IMPLEMENTATION OF THE INLAND AVIAN PREDATION MANAGEMENT PLAN, 2015

Final Report

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EXECUTIVE SUMMARY

In 2015, the U.S. Army Corps of Engineers - Walla Walla District and the U.S. Bureau of Reclamation continued implementation of the Inland Avian Predation Management Plan (IAPMP) in order to reduce predation by Caspian terns (*Hydroprogne caspia*) on U.S. Endangered Species Act (ESA)-listed populations of salmonids (*Oncorhynchus* spp.) from the Columbia River basin (USACE 2014). The primary objective of management in the second year of implementation of the IAPMP was to reduce the size of the Caspian tern breeding colonies on Goose Island in Potholes Reservoir and on Crescent Island in the mid-Columbia River to less than 40 breeding pairs each. To accomplish this task, the availability of suitable Caspian tern nesting habitat was reduced on both islands by installing a variety of "passive nest dissuasion" materials designed to preclude tern nesting over extensive areas on both islands prior to the 2015 nesting season. Ultimately, about 4.1 acres, or more than 85% of the upland area on Goose Island and its surrounding islets, were covered with passive nest dissuasion materials consisting exclusively of stakes, rope, and flagging. On Crescent Island, about 2.2 acres of potential Caspian tern nesting habitat were covered with passive nest dissuasion materials consisting of fences rows of privacy fabric, stakes, rope, flagging, and woody debris. On both islands, passive dissuasion was placed over all of the former Caspian tern nesting area, as well as all areas of open sparsely-vegetated habitat that might be used by ground-nesting Caspian terns or gulls (*Larus* spp.). An effort was also made to prevent nesting by the two species of gulls that nest abundantly on both islands (California gulls [*L. californicus*] and ring-billed gulls [*L. delawarensis*]), on the theory that nesting gulls would attract prospecting Caspian terns and could limit the ability to dissuade Caspian terns from nesting on the two islands. Once Caspian terns and gulls arrived on Goose and Crescent islands to initiate nesting, active nest dissuasion (i.e. human hazing) was used to dissuade both Caspian terns and gulls from nesting anywhere on either island.

Both California and ring-billed gulls quickly acclimated to both the passive and active dissuasion employed at Goose Island and, as occurred in 2014, initiated nesting (laid eggs) despite our dissuasion efforts. Once gulls laid eggs, hazing gulls that were attending eggs was precluded due to the risk of gull nest failure. As the area on Goose Island with active gull nests expanded, the opportunities to actively haze Caspian terns that were prospecting for nest sites on Goose Island declined. Nevertheless, between the passive dissuasion deployed on typical Caspian tern nesting habitat, and active dissuasion (hazing) including a green laser, only two pairs of Caspian terns succeeded in laying eggs and raising young on Goose Island and nearby islets in 2015. These two nests were not located together, but both were near the former colony area on the main island under nest dissuasion materials. Nesting by Caspian terns on the Northwest Rocks, site of the Caspian tern colony at Goose Island in 2014, was precluded in 2015 using a combination of passive and active dissuasion techniques.

Despite the lack suitable Caspian tern nesting habitat on Goose Island in 2015, some Caspian terns displayed considerable breeding site fidelity to Pothole Reservoir area throughout the nesting season, likely due to the history of Caspian tern nesting on Goose Island since 2004 and

the presence of a large gull colony on the island that persistently attracted prospecting Caspian terns to the site. Another factor that might explain the strong site fidelity of Caspian terns to Potholes Reservoir area is the paucity of alternative Caspian tern colony sites in the vicinity. Caspian tern use of Goose Island for roosting and nesting was largely limited to areas near the shoreline where passive nest dissuasion had not been installed. Active nest dissuasion (hazing), collection of any Caspian tern eggs discovered, and high rates of gull predation on newly-laid Caspian tern eggs were successful in preventing the formation of a sizable Caspian tern colony on Goose Island. A total of 43 Caspian tern eggs were found on Goose Island and nearby islets in 2015, and these eggs were laid in 39 nest scrapes. Seventeen Caspian tern eggs were collected under permit, 23 eggs were depredated by gulls soon after laying, and three producing chicks (see above).

Passive and active nest dissuasion techniques were successful in preventing nesting and roosting by both Caspian terns and gulls on Crescent Island in 2015. This result was somewhat unexpected because it was the first year that nest dissuasion was implemented at Crescent Island and because Caspian terns and gulls have nested consistently on Crescent Island for nearly three decades. One factor that likely contributed to the absence of nesting Caspian terns on Crescent Island was the use of closely-spaced fence rows of privacy fabric as passive dissuasion over much of the suitable Caspian tern nesting habitat on Crescent Island; similar fencing was not deployed at Goose Island due to shallow rocky soils. Another factor was the successful dissuasion of all nesting gulls from Crescent Island in 2015; gulls are breeding associates of Caspian terns and attract prospecting Caspian terns to nest near their colonies. At Goose Island, gull nesting could not be prevented using the passive and active dissuasion techniques at our disposal, whereas at Crescent Island gulls never habituated to our hazing techniques and abandoned Crescent Island to establish a new colony on Badger Island (located on the mid-Columbia River just one kilometer upstream from Crescent Island) in 2015. Similarly, Caspian terns displaced from Crescent Island were able to relocate to an alternative colony site on the mid-Columbia River, the Blalock Islands (70 river kilometers downriver from Crescent Island), where Caspian terns have nested in small numbers over the last decade. Resightings of terns that were color-banded previously indicated that the Blalock Islands experienced a large influx of Caspian terns from the Crescent Island colony in 2015.

System-wide action effectiveness monitoring confirmed that Caspian terns attempted to nest at four historical colony sites in 2015: the Blalock Islands on the mid-Columbia River (677 breeding pairs), Twinning Island in Banks Lake (64 breeding pairs), Harper Island in Sprague Lake (10 breeding pairs), and an unnamed island in Lenore Lake (16 breeding pairs). The Caspian tern colonies on Twinning Island, Harper Island, and the small island in Lenore Lake were similar in size (i.e., number of breeding pairs) in 2015 compared to the previous year, while the tern colony in the Blalock Islands increased from 45 breeding pairs in 2014 to 677 breeding pairs in 2015. This also represented an increase in Caspian tern colony size at the Blalock Islands compared to the historical average (2005-2014; 58 breeding pairs).

The total estimated breeding population of Caspian terns in the Columbia Plateau region during 2015 was 769 breeding pairs at five separate colonies. All but one of the six Caspian tern colonies that were active in the region during 2014 were active again in 2015; the exception was the Crescent Island colony, where nest dissuasion efforts were successful in preventing Caspian terns from nesting in 2015. The estimated total size of the breeding population of Caspian terns in the Columbia Plateau region in 2015 (769 breeding pairs) was similar to the estimated population size in 2014 (755 breeding pairs), but still generally lower than the numbers observed during 2000-2013. These results suggest that although nest dissuasion actions implemented on Goose and Crescent islands in 2015 were highly effective in reducing the numbers of Caspian terns nesting at these two colonies, formerly the largest Caspian tern colonies in the region, they did not result in a significant reduction in the total number of Caspian terns breeding in the region to date. This was due to the more than 10-fold increase in the number of Caspian tern nesting in the Blalock Islands in 2015 compared to 2014. The Blalock Islands colony in 2015 was similar in size to the largest Caspian tern colony recorded anywhere in the Columbia Plateau region since intensive monitoring began in 2000.

Resightings of terns that were color-banded previously indicated that some Caspian terns exhibited site fidelity to Potholes Reservoir area, and the Blalock Islands experienced a large influx of Caspian terns from the Crescent Island colony in 2015. Evaluation of inter-regional movements of Caspian terns revealed net movements to the Columbia River Plateau region from the managed colony at East Sand Island and from the Corps-constructed alternative colony sites in interior Oregon and northeastern California in 2015; the latter region experienced severe drought in 2015.

Based on an analysis of per capita (per bird) predation rates by Caspian terns nesting at various colonies in the Columbia Plateau region during 2007-2014, predicted predation rates in 2015 were less than 2% (the goal of the IAPMP) on many, but not all, ESA-listed salmonid populations. Specifically, predicted predation rates on ESA-listed Upper Columbia River steelhead were below 2% for Caspian terns nesting at Potholes Reservoir in 2015 for the first time since management was initiated in 2014. Also, predicted predation rates on ESA-listed Snake and Upper Columbia River salmonid populations by Caspian terns nesting on Crescent Island were close to zero due to a lack of nesting adults at Crescent Island in 2015. Because of the large size (677 breeding pairs) of the Caspian tern breeding colony at the Blalock Islands, however, predicted predation rates were above the 2% threshold for Upper Columbia River steelhead (6.3%; 95% prediction interval [PI] = 4.8-8.7%), Snake River steelhead (4.8%; 95% PI = 3.9-6.1%) and Snake River sockeye (2.7%; 95% PI = 0.6-7.7%) in 2015, losses that partially or completely offset benefits achieved by reduced predation rates by Caspian terns nesting at Goose and Crescent islands in 2015. Due to a lack of adequate historical predation rate data from Caspian terns nesting on Twinning Island, predicted predation rates were not available for this colony in 2015.

PROJECT OBJECTIVES

The primary objectives of this study in 2015 were to (1) implement components of the Inland Avian Predation Management Plan (IAPMP; USACE 2014), including adaptive management actions, in order to dissuade Caspian terns (*Hydroprogne caspia*) from nesting on Goose and Crescent islands (2) monitor the efficacy of those management components and actions at both the colony- and system-level, (3) measure the inter-colony movements of previously color-banded Caspian terns, and (4) model the change in predation rates on juvenile salmonids (*Oncorhynchus* spp.) by Caspian terns in the Columbia Plateau region (see *Map 1*) concomitant with management actions implemented as part of the IAPMP.

To address *Objective 1* we sought to (a) dissuade all Caspian terns from nesting using passive measures (i.e. stakes, rope, flagging, and owl decoys on Goose Island and a combination of silt fences, stakes, rope, flagging, and woody debris on Crescent Island) installed prior to the initiation of nesting activities by gulls (*Larus* spp.) and Caspian terns at each island; (b) use active hazing (i.e. targeted use of human disturbance on land and by boat, green lasers, peregrine falcon kite) as an adaptive management technique to prevent Caspian terns, and other birds as necessary, from nesting at Goose and Crescent islands; (c) collect any Caspian tern eggs laid on Goose Island or Crescent Island, under permit (i.e. egg take permits issued by the USFWS under the Migratory Bird Treaty Act) and according to Best Management Practices guidelines developed by Oregon State University/Real Time Research and approved by the Corps and Reclamation; and (d) test the feasibility of using willow plantings on Crescent Island as a more natural and sustainable nesting deterrent for Caspian terns over the long term.

Action effectiveness monitoring (*Objective 2*) included both colony-level monitoring and system-level monitoring. Colony-level monitoring was conducted in support of the IAPMP at both Goose Island and Crescent Island. Monitoring at both islands was conducted daily by resident field crews throughout the breeding season (i.e. late February to mid-July). Data collection at each island was conducted according to established protocols (see BRNW 2014a, BRNW 2014b, BRNW 2015a) and included the following colony metrics: (a) temporal and spatial distribution of Caspian terns and gulls on each island; (b) daily activities (behavior) of Caspian terns and gulls, including any nesting attempts by Caspian terns; (c) seasonal attendance (counts) of nesting and roosting Caspian terns and gulls; (d) types of habitat used by nesting and roosting Caspian terns and gulls; (e) the area (acreage) used by nesting and roosting Caspian terns and gulls; (f) formation of any incipient Caspian tern or gull colonies on or in the immediate vicinity of either island; (g) peak colony size for Caspian terns and gulls; (h) number of Caspian tern eggs laid and the disposition of those eggs; and (i) Caspian tern nesting success and nesting density, if applicable.

System-level monitoring was conducted in support of both the IAPMP (USACE 2014) and the Caspian Tern Management Plan for the Columbia River Estuary (USFWS 2005, 2006). System-level monitoring of Caspian tern colonies was carried out in the Columbia Plateau region (results reported here), and in southeastern Oregon, northeastern California (results presented in BRNW 2015b), and at Don Edwards National Wildlife Refuge (NWR) in San Francisco Bay (results presented in a separate report prepared by U.S. Geological Survey – Dixon Field Station). The monitoring in the Columbia Plateau region was conducted periodically and as necessary to determine the locations of all active or incipient Caspian tern breeding colonies in the region. At each of these Caspian tern colony locations, we measured (a) seasonal colony attendance, (b) nesting chronology and behavior, (c) nesting habitat types used, (d) nesting area occupied, (e) peak colony size (number of breeding pairs), and (f) number of nests initiated and young fledged (i.e. nesting success), if feasible. Monitoring was by periodic aerial, ground-based, and/or boat-based surveys. At all sizeable Caspian tern colonies (> 40 breeding pairs) in the Columbia Plateau region, digital aerial photography was used to accurately measure the colony area by habitat type, the number of Caspian terns present, and the peak Caspian tern colony size.

Objective 3 was addressed by systematically resighting previously color-banded Caspian terns during visits to the Goose Island, Crescent Island, and other nesting or roosting sites used by Caspian terns in the Columbia Plateau region during 2015. Using a comprehensive database containing banding and resighting records for Caspian terns dating back to 2006, we assessed (a) colony connectivity among sites in the Columbia Plateau region, (b) emigration rates of banded individuals from colony sites in the Columbia Plateau region to colony sites outside the region, and (c) immigration rates of banded individuals from colony sites outside the Columbia Plateau region to sites in the region. This information will help assess to what extent Caspian tern management actions implemented as part of the IAPMP (USACE 2014) and the Caspian Tern Management Plan for the Columbia River Estuary (USFWS 2005, 2006) are successful in relocating Caspian terns to sites outside the Columbia River basin.

Finally, the ultimate goal of the IAPMP is to reduce predation rates on juvenile salmonids by Caspian terns to less than 2% of each ESA-listed salmonid population (hereafter ESU/DPS), per Caspian tern colony, per year in the Columbia Plateau region (USACE 2014). As part of *Objective 4*, we estimated the number of Caspian terns residing at breeding colonies in the Columbia Plateau region during 2015. We used this information and previously measured colony-specific per-capita predation rates to model predation rates by Caspian terns from each sizeable breeding colony in 2015. Per-capita predation rates were estimated using smolt PIT tags recovered on Caspian tern colonies in the region during 2007-2014, all of which, with the exception of Crescent Island, were used by nesting Caspian terns in 2015. This modeling will be used to evaluate to what extent the overriding management goal is being met, and where additional or modified management efforts might be implemented to meet that goal.

METHODS & ANALYSIS

PASSIVE NEST DISSUASION

To deter Caspian terns from nesting on Goose Island and the surrounding islets in Potholes Reservoir (hereafter referred to as “Goose Island”) and on Crescent Island in the mid-Columbia River during 2015, a network of passive dissuasion was constructed during March 2015, prior to the arrival of breeding Caspian terns and gulls to the islands. Following proven methods developed in the Columbia River estuary (BRNW 2015a, BRNW 2014a), and as described in the IAPMP (USACE 2014), we erected a matrix of vertical silt fences, stakes, polypropylene rope, and polyethylene flagging over historical Caspian tern nesting areas and other areas that were considered to be potentially suitable Caspian tern nesting habitat on both islands. Woody debris and owl effigies were added as additional passive nesting deterrents. The passive nest dissuasion materials and configurations differed between islands and are described below.

At Crescent Island[1], stems of native willows (*Salix* spp.) were planted in a plot prior to the 2014 nesting season to test the feasibility of using willow plantings as a more natural and sustainable nesting deterrent for Caspian terns. In 2015, we continued to monitor the growth and survival of these test plantings as described in detail below.

Goose Island

Prior to the installation of new passive nest dissuasion materials on Goose Island in 2015, a thorough inspection of the materials installed in 2014 was conducted on 16 February to determine the need for repairs and additional materials. Repairs and installation of replacement flagging was initiated on 18 February. Additional passive nest dissuasion materials were delivered to Goose Island on 25 February using a helicopter (General Aircraft Services, Pendleton, OR) and boats. The installation of additional materials was initiated on 26 February. As in 2014, concrete pier blocks (Mutual Materials; 12'' x 12'', 63 lbs. each) were placed in a 10' x 10' square grid in areas where additional passive dissuasion was considered necessary. The center of each concrete pier block was drilled out vertically to accommodate a 48-inch length of .5-inch rebar and a 42-inch length of .5-inch PVC pipe was slipped over the rebar. Twisted polypropylene rope (.25-inch) was then attached to the PVC at approximately 42" above ground level (AGL) using clove hitch knots, and the rope was further secured to the pipe using UV-resistant cable ties. Ropes were fastened to the vertical PVC pipes to form a 10' x 10' grid, with each grid square also bisected diagonally with a section of rope (see USACE 2014 for grid design). Four-foot-long pieces of industrial barricade tape ("polyethylene flagging;" Mutual Industries; 3 mil) were inserted between the strands of the rope at approximately 3-foot intervals, and allowed to flutter in the wind as a visual deterrent to prospecting Caspian terns. A second layer of ropes and flagging was added below the initial layer forming a "double layer" in certain areas where Caspian terns were considered most likely to attempt nesting. In general, a 10 to 15 foot buffer of double layer passive nest dissuasion was installed around the perimeter of all contiguous areas of passive dissuasion (see *Map 2*). Additionally, areas where nesting by Caspian terns had occurred in previous years, and areas identified in 2014 as suitable Caspian tern habitat, were again covered with a double layer of passive dissuasion.

The installation of 3.5 acres of passive dissuasion on Goose Island was completed by 12 March. This was accomplished by first re-deploying materials (primarily barricade tape) on the 2.39-acre area where passive nest dissuasion was installed in 2014. Additional passive nest dissuasion (1.11 acres) was then installed primarily in the southern half of Goose Island, where Caspian terns were observed prospecting and where a few laid eggs in 2014, and on the rocky islet dubbed "Northwest Rocks," where Caspian terns successfully nested in 2014 (BRNW

[1] Willow plantings are not a feasible option as a nesting deterrent for Caspian terns on Goose Island due to the rocky substrate found on that island.

2015a). Following the arrival of Caspian terns to Goose Island in 2015 and their subsequent prospecting for nest sites in marginal habitat at or below the high waterline, the action agencies authorized the deployment of additional passive nest dissuasion at the shoreline of Goose Island and the surrounding rocky islets. An additional 0.6 acres of passive nest dissuasion was installed in these areas in mid-April. In total 4.1 acres of passive nest dissuasion were deployed on Goose Island and surrounding islets during 2015.

More than 1,800 pier blocks, rebar stakes, and PVC sections were installed on Goose Island to support the rope and flagging matrix that covered 4.1 acres, more than 85% of the upland area of Goose Island (see *Map 2*). Virtually all of the previously used and potential Caspian tern nesting habitat that was above the waterline during mid-April was covered in passive nest dissuasion materials.

Finally, owl effigies (provided by the Bureau) were deployed in late April to determine their utility as a passive dissuasion technique on Goose Island. Two plastic owl decoys were mounted on two outlying rocky islets (Northeast Rocks and East Rocks; see *Map 2*) that were used by roosting Caspian terns early in the 2015 breeding season.

Crescent Island

Installation of the passive nest dissuasion materials on Crescent Island was initiated on 2 March and completed by 14 March. A series of parallel fence rows spaced 15’ apart were constructed across the former Caspian tern colony site and nearby sparsely vegetated areas, as well as in a second large, sparsely vegetated area in the southern part of the island. Additional fence rows were constructed along the perimeter of the island where continuous vegetation was not present at the island edge, and to bisect other large open areas. Fence rows were constructed by driving commercial grade painted steel, 6-foot fence posts into the ground to depths of at least two feet. Along each fence row, fence posts were spaced no more than six feet apart, and each fence row was securely anchored at both ends using specially designed angle brackets (Wedge-Loc®). Runs of taught, barbless wire were then secured to the fence posts at ground level, at 18 inches AGL, and at 36 inches AGL. Commercial grade knitted material (PAK Unlimited Inc.; 90% privacy screen) was then zip tied to the top and bottom wire strands to create a visual barrier for any prospecting Caspian terns that might land on the ground. Fence rows were constructed across the entirety of the “Primary Dissuasion Area” and much of the “Secondary Dissuasion Areas” identified in the IAPMP (see *Map 3*). Additionally, twisted polypropylene rope (0.25-inch) was then attached to the fence posts at approximately 42 inches AGL using clove hitch knots. Ropes were fastened to alternating fence posts diagonally between two adjacent fence rows, and then 4-foot lengths of industrial barricade tape (“polyethylene flagging;” Mutual Industries; 3 mil) were inserted between strands of the rope at 3-foot intervals.

In open areas where Caspian terns were less likely to prospect for nest sites due to the proximity of mature woody vegetation, passive dissuasion consisting of stakes, rope, and flagging or woody debris was used to cover any potential Caspian tern nesting habitat. Ropes and flagging were deployed in a 10-foot by 10-foot square array using 6-foot steel fence posts driven into the ground, and with diagonal strands of rope and flagging bisecting each square. Similar to the passive dissuasion installed on Goose Island (*see above*), a double layer of rope and flagging was deployed at or near the high waterline around the island's periphery, where fence rows could not be constructed. Woody debris was collected from downed dead trees and felled Russian olive trees (*Laeagnus angustifolia*; a non-native invasive plant) that did not contain heron or egret nest structures. This woody debris was placed primarily on the west side of Crescent Island, where nest prospecting was considered possible but unlikely, and in open areas below the high waterline.

In total, approximately 2.2 acres of potential Caspian tern nesting habitat was covered in passive nest dissuasion, consisting primarily of fence rows, rope, and flagging. Virtually all of the sparsely vegetated upland areas of Crescent Island were eliminated as potential Caspian tern nesting habitat through the deployment of passive nest dissuasion materials prior to the 2015 nesting season (see *Map 3*).

In 2014, stems of native willows were planted in a test plot on Crescent Island near the former Caspian tern colony site to test the feasibility of planting willow stems as a method to dissuade Caspian terns from nesting on Crescent Island over the long-term. Results from the test planting would inform adaptive management efforts and actions taken as part of the IAPMP (USACE 2014). If deemed feasible, willow plantings may be used to reduce or eliminate nesting habitat for Caspian terns on Crescent Island.

In 2015, we continued to monitor the test plot of native willow stems planted on Crescent Island prior to the 2014 nesting season. The goal of this work was to identify factors that may limit growth and survival of willow stems planted in the test plot. For the initial planting in 2014, the source of willow stems, the number of willow stems planted per planting hole, and the soaking treatment for stems were varied among plantings to generate five different treatments for comparison: (1) willow stems from Two Rivers Park, single stem per planting, stems soaked in water prior to planting; (2) willow stems from Two Rivers Park, single stem per planting, stems not soaked in water prior to planting; (3) willow stems from Two Rivers Park, five stems per planting, stems soaked in water prior to planting; (4) willow stems from Two Rivers Park, five stems per planting, stems not soaked in water prior to planting; and (5) willow stems from Crescent Island, five stems per planting, stems soaked in water prior to planting. Each of the five willow planting treatments were assigned randomly to five different planting holes in the upper third (rows 1-5), middle third (rows 6-10), and lower third (rows 11-15) of the test plot, such that 15 different planting holes were assigned to each treatment across the entire test plot of 75 willow planting holes. Data collected on the planted willow stems in the test plot during the 2015 growing season included the same growth and condition variables collected at the end of the first growing season (August 2014; BRNW 2014b), plus additional metrics of willow stem growth and survival.

ACTIVE NEST DISSUASION

In accordance with the IAPMP, active nest dissuasion methods were used to supplement passive dissuasion measures to deter nesting attempts by Caspian terns and gulls on Goose and Crescent islands in 2015 (USACE 2014). These active dissuasion methods were conducted from early March through July, and included: (1) forays into the colony by researchers to haze prospecting birds, (2) approaching the shoreline of the island by boat to haze prospecting birds along the shore, (3) using a green laser during low light conditions to haze prospecting birds on the ground, and (4) flying a peregrine falcon kite to deter birds on or near the island from landing. A detailed description of active nest dissuasion activities that were used at each island during the 2015 nesting season is provided below. Active hazing targeted both Caspian terns and gulls (i.e. ring-billed gulls [*L. delawarensis*] and California gulls [*L. californicus*) in an attempt to prevent or delay colony formation. The purpose of active gull nest dissuasion was to prevent or delay gull nesting because nesting gulls attract Caspian terns to nest. In addition, the initiation of gull nests over much of the islands would limit or preclude researcher access to the island in order to conduct the management described below (see *Appendix A: Best Management Practices* for more details).

Goose Island

Active nest dissuasion was conducted at Goose Island by (1) forays into the colony by researchers, (2) approaching the shoreline of the island by boat, (3) targeted use of a green laser during low light conditions, and (4) flying a peregrine falcon kite on the island (collectively referred to as “active hazing”). Active hazing was performed on Goose Island and the surrounding small rocky islets (see *Map 4*).

On 2 March, an observation blind was installed on the upper part of Goose Island, adjacent to the former Caspian tern colony site (see *Map 4*). The blind was visited twice daily to monitor Caspian tern and gull use of the surrounding area of the island, which cannot be readily seen from a boat. On 19 March, a portable building was installed on Goose Island as a field camp (see *Map 4*) to facilitate overnight stays on the island and to allow early morning and late evening hazing of Caspian terns and gulls from potential nesting areas. Evening hazing to prohibit Caspian terns and gulls from remaining on Goose Island overnight was considered especially important for deterring, or at least delaying, nest initiation.

In accordance with Best Management Practices (BMPs; see *Appendix A*) developed during the 2014 nesting season and revised in 2015, the frequency, duration, and methods of active hazing were altered over the course of the breeding season to enhance the efficacy of Caspian tern nest dissuasion and to avoid egg take of non-target species (i.e. gulls and Canada geese). Methods to dissuade prospecting Caspian terns and gulls during 26 February through 4 March included incidental disturbance caused by researchers installing and monitoring passive dissuasion materials and intentional, but opportunistic, hazing of prospecting birds when observers walked across the island (hereafter referred to as “walk-throughs”). Beginning on 5 March, hazing frequency was increased to two 1-hour walk-through sessions daily, and all hazing sessions were recorded to document effort and the response of hazed birds. On 20

March, hazing session frequency and duration was increased to two 3-hour walk-through sessions, a morning session that started before dawn and an evening session that ended after dark. On 31 March, a 2-hour afternoon hazing session was added, bringing the total daily duration of active dissuasion to at least eight hours. Hazing effort was increased further as needed in response to intensified nesting activities by Caspian terns and gulls.

During each walk-through, any gull or Canada goose nest observed was recorded and nests that did not contain eggs were destroyed by the observer. The BMPs, which described the procedures for colony monitoring, active hazing, Caspian tern egg collection, and communication/reporting (see *Appendix A*), were followed closely throughout. In addition to active human hazing, a peregrine falcon kite was flown by researchers during morning and evening hazing sessions from 25 March to 3 April to determine the utility of this method as a supplement to active dissuasion. This technique was implemented after observing the response of gulls and Caspian terns to visits by a live peregrine falcon (*Falco peregrinus*) to Goose Island.

Once the widespread initiation of gull nests curtailed or precluded walk-throughs of Goose Island, the primary techniques used to actively dissuade prospecting Caspian terns were the use of a green laser (Agrilaser®; LEM 50) during low-light conditions from a boat and using boat-based approaches to flush prospecting Caspian terns that were near the water's edge. The laser allowed hazing of individual Caspian terns that were loafing or prospecting on Goose Island without disturbing nesting gulls that were attending eggs nearby. Personnel who were engaged in active hazing of prospecting Caspian terns also approached the island in a boat, sometimes landing on the shore, to flush Caspian terns without disturbing nesting gulls.

Beginning on 18 April, the combination of boat approaches and/or laser hazing was conducted over a 3-hour period early in the morning, a 2-hour period in the afternoon, and a 3-hour period in the evening (weather permitting). Morning and evening hazing sessions began and ended at civil twilight (30 min before sunrise and 30 min after sunset, respectively). The second hazing session of the day was conducted in the early afternoon for at least two hours, depending on the presence of prospecting Caspian terns. The third hazing session of the day started in the early evening 2.5 – 3.0 hours before dusk. On occasions when Caspian terns showed a greater interest in nesting on Goose Island (i.e. when copulation, nest-scraping, or egg-laying were observed), daytime hazing and monitoring were temporarily increased and conducted nearly continuously until nesting behaviors abated.

On 16 May, after a Caspian tern nest with eggs was discovered under the passive dissuasion materials near the former colony site on Goose Island, researchers initiated two additional hazing sessions using the green laser from the observation blind adjacent to the former colony. The second hazing session of the day was initiated from the blind within one hour of ending the first session and generally lasted two hours, while the fifth hazing session of the day was initiated from the blind at dusk using the laser and lasted about one hour.

Due to the presence of nesting Forster's terns (*Sterna forsteri*) on Goose Island, hazing efforts were more carefully executed or were avoided entirely on some parts of the island beginning on 21 May. The primary locations where Forster's tern nesting affected active hazing efforts for Caspian terns included the South Spit and Southwest Tip of Goose Island, as well as Northwest Rocks, East Rocks, and Northeast Rocks (see *Map 4*). Although hazing of Caspian terns was reduced or curtailed after 21 May at these sites, prospecting Caspian terns were uncommonly observed at these Forster's tern nesting areas because of territorial aggression by nesting Forster's terns.

As prospecting by Caspian terns on Goose Island waned later in the nesting season, active hazing efforts were reduced. On 22 June, pre-dawn hazing with the laser from the blind was discontinued due to a major reduction in prospecting behavior by Caspian terns on or near the former Caspian tern colony site on Goose Island. Morning hazing sessions were reduced to two hours, beginning at 07:00 using walk-throughs or boat approaches for areas inaccessible by foot. Overnight use of the camp by researchers was suspended on 26 June. On 3 July, active hazing of Caspian terns was further reduced to just 1.5 hours in the morning and 1.5 hours in the evening, with no afternoon session. Active hazing of Caspian terns was terminated on 27 July, and the final survey of Goose Island for the season occurred on 7 August.

A limited number of Caspian tern eggs were permitted to be removed from nests initiated on Goose Island, if Caspian terns laid eggs despite our efforts to prevent egg-laying. The collection of any Caspian tern eggs that were laid on Goose Island was intended to enhance the prospects for successfully dissuading Caspian terns from initiating nests and forming a breeding colony (*see below* for a description of the collection and disposition of Caspian tern eggs on Goose Island).

Finally, to monitor fluctuations in water level at Potholes Reservoir and how water level influenced seasonal availability of suitable nesting habitat for Caspian terns along the shoreline of Goose Island, a vertical meter stick was installed in the reservoir near the Goose Island camp on 10 May.

Crescent Island

Active nest dissuasion was conducted to disrupt nesting attempts by Caspian terns and gulls on Crescent Island by (1) forays into the colony by researchers, (2) approaching the shoreline of the island by kayak, (3) use of a green laser during low light conditions, and (4) flying a peregrine falcon kite on the island (collectively referred to as "active hazing"; see *Map 5*). As on Goose Island, and for the reasons described above, active hazing targeted both prospecting Caspian terns and prospecting ring-billed and California gulls in an attempt to prevent or delay the onset of egg-laying by these colonial waterbird species.

Because camping is not permitted on Crescent Island, a houseboat was transported to Crescent Island and anchored in the cove (see *Map 5*) on 20 March. The houseboat allowed overnight stays near the island, and facilitated early morning and late evening sessions of active hazing to dissuade nesting by Caspian terns and gulls. Evening hazing to prevent Caspian terns and gulls from remaining on Crescent Island overnight was considered especially important for deterring, or at least delaying, nest initiation. Researchers were present at or near Crescent Island nearly continuously from 25 March to 30 May.

Methods of active hazing were adaptively modified over the course of the breeding season to enhance the efficacy of Caspian tern and gull nest dissuasion, and to avoid egg take of non-target species (e.g., Canada geese; see *Appendix A: Best Management Practices*). Methods to dissuade prospecting Caspian terns and gulls during 2 - 14 March included incidental disturbance caused by researchers installing passive dissuasion materials (see *Methods & Analysis: Passive Nest Dissuasion*) and intentional, but opportunistic hazing of prospecting Caspian terns and gulls when observers conducted island walk-throughs. During each walk-through, any gull or goose nests observed were recorded and nests that did not contain eggs were destroyed by the observer. As was done on Goose Island, the revised BMPs (see *Appendix A*) were followed for colony monitoring, active hazing, Caspian tern egg collection, and necessary communication and reporting of field activities. BMPs were written and revised by project personnel, and approved by POCs from the Corps and Bureau, to minimize researcher disturbance and avoid unpermitted take of non-target nesting species (egg loss).

Other dissuasion techniques used to supplement island walk-throughs at Crescent Island primarily included the use of a green laser (Agrilaser®) from land during low-light conditions, and waving a 10-foot PVC pole with caution tape tied to each end. Using these methods, gulls observed rafting in the water near the island were hazed to positions further from the island, and gulls hovering over Crescent Island were prevented from landing, or quickly flushed upon landing. On occasion, researchers also used kayaks to haze gulls from the shoreline of the island, areas that were not always accessible by foot due to the presence of Canada goose nests with eggs (see *Appendix A: Best Management Practices*). Additionally, a peregrine falcon kite was briefly tested during morning and evening hazing sessions to determine its utility as an alternative method of active nest dissuasion (*see above*).

Beginning on 16 March, walk-throughs were conducted each day before 10:00 and after 15:00, and all hazing sessions were recorded to document effort and response of hazed birds. During 19 - 25 March, gull hazing was conducted during intermittent island walk-throughs between sunrise and sunset, until the arrival of the houseboat allowed for pre-dawn and post-dusk hazing efforts. Beginning on 26 March researchers used the PVC pole with flagging during walk-throughs to more effectively haze all gulls from the island. Active hazing methods were again modified on 5 April, when researchers increased the frequency of walk-throughs and were successful in preventing any gulls from landing on the island for more than 24 hours. Consequently, researchers began conducting walk-throughs with the PVC pole whenever gulls were observed hovering over the island, about every 45 - 90 min, with each hazing session lasting 10 - 25 min. Beginning on 9 May, in response to a reduction in the frequency and intensity of gulls hovering over the island, active hazing efforts were reduced on Crescent Island. Beginning on 22 May, in response to limited hovering behavior by gulls over Crescent Island, actual active hazing was reduced. Active hazing sessions continued, as described below, but the absence of gulls and terns at Crescent Island meant that hazing effort (in minutes) was reported as zero.

Following concurrence from the action agencies on 30 May, researchers terminated their continuous presence on or near Crescent Island. From 30 May to 6 June, researchers were present on or near Crescent Island for four hours each day, consisting of a 2-hour morning and a 2-hour evening active hazing session. Active hazing sessions were further reduced to a single daily visit during 8 - 17 June; the last survey of Crescent Island during the 2015 nesting season was conducted on 31 July.

ACTION EFFECTIVENESS MONITORING

Action effectiveness monitoring was conducted both at the colony-level and the system-level (region-wide). Colony-level monitoring was accomplished by resident field crews stationed at both Goose Island and Crescent Island, in conjunction with management tasks described above. Colony-level monitoring was to evaluate the efficacy of nest dissuasion efforts on Goose and Crescent islands in preventing Caspian terns from nesting at these two colony sites (*see below* for more details).

System-level monitoring consisted of periodic, carefully-timed aerial photography surveys (see *Table 1*) in the Columbia Plateau region to locate both active and incipient Caspian tern breeding colonies, estimate colony size, and evaluate nesting success at each colony. In addition, periodic ground- and boat-based surveys were carried out by a mobile field crew (separate from the island-based field crews mentioned above) at all active or incipient Caspian tern breeding colonies that were identified during aerial surveys; these ground- or boat-based surveys were intended to accurately assess nesting chronology, colony attendance, and colony size, as well as to determine the outcome of any nesting attempts (i.e. nesting success). System-level monitoring was completed with cost-sharing from the Grant County Public Utility District (GPUD)/Priest Rapids Coordinating Committee (PRCC).

Colony-level Monitoring

Monitoring of Caspian tern nesting attempts at Goose and Crescent islands was necessary to determine the success of passive and active dissuasion of nesting Caspian terns during the 2015 breeding season. With the installation of passive nest dissuasion materials on the former colony sites and in most, but not all, of the sparsely vegetated habitat on each island, it was anticipated that some Caspian terns would attempt to nest at new nesting areas outside the passive nest dissuasion on each island or at completely different colony sites. Consequently, a combination of ground-, boat-, and blind-based monitoring, together with oblique and high-resolution vertical aerial photography, were used to assess Caspian tern colony formation, seasonal colony/island attendance by Caspian terns, peak colony size, nesting success, habitat use, and the area of habitat used by nesting terns at each colony site. These data were used to assess Caspian tern use of each colony site in 2015. Furthermore, these data were used to estimate the size of the breeding population of Caspian terns in the Columbia Plateau region during 2015 (see *Methods & Analysis: System-level Monitoring*).

We continuously (7 days/week) monitored the activities of Caspian terns and other colonial waterbirds (i.e. gulls) on Goose and Crescent islands from mid-March through July using two field crew members stationed on or near each island. Monitoring of nesting and roosting terns and gulls was conducted using early morning ground counts of adults made by observers in a blind located near the edge of the former colony area, by boat, and on foot in areas with potential for minimal disturbance to actively nesting gulls, geese, or other protected migratory birds. Additional counts were made throughout the day while conducting active hazing efforts to assess action effectiveness of passive and active nest dissuasion measures. Seasonal attendance by adult terns and gulls at each island was estimated based on the average number of adults counted from the ground each week throughout the breeding season. Each island was also closely monitored for the formation of new Caspian tern satellite colonies (i.e., away from the former colony site and outside areas of passive nest dissuasion) and, once detected, the incipient Caspian tern nest sites were periodically checked to determine the number of tern nests initiated and the ultimate fate of all Caspian tern nesting attempts.

Estimates of Caspian tern colony size and nesting success on Goose and Crescent islands were based on ground counts of active nests (i.e., adult Caspian terns attending nests with eggs or nestlings) and counts of pre-fledged tern chicks (i.e., chicks in the black-capped stage of plumage development on or near the colony), respectively. These ground counts were made by researchers from observation blinds or vantages at the periphery of each tern colony. Data collection methodologies used as part of this study followed established protocols such that the data collected in 2015 could be compared with analogous data collected in previous years and at other colonies (Antolos et al. 2004; Adkins et al. 2014; BRNW 2014a; BRNW 2014b; BRNW 2015a; *see below* for more details).

High-resolution, vertical, aerial photography was taken of Goose and Crescent islands on 20 May and those ortho-rectified images were analyzed to estimate the total area (in acres) covered by passive nest dissuasion materials on each island and to count nesting gulls and estimate the area (in acres) occupied by nesting gulls on Goose Island.

System-level Monitoring

The geographic scope of the IAPMP includes the 10 “at-risk” sites identified in the IAPMP and other sites within the Columbia Plateau region where Caspian terns displaced from colonies on Goose and Crescent islands may relocate following management (USACE 2014). These alternative colony sites (hereafter referred to as “prospective sites”) include islands where Caspian terns have recently nested (i.e. within the last two years), including the Blalock Islands (John Day Reservoir), Twinning Island (Banks Lake), Harper Island (Sprague Lake), and Lenore Lake. Prospective colony sites also include sites where Caspian terns have previously, but not recently nested, including Miller Rocks (The Dalles Reservoir), Three Mile Canyon Island (John Day Reservoir), Badger Island (McNary Reservoir), Foundation Island (McNary Reservoir), Cabin Island (Priest Rapids Reservoir), and Solstice Island (Potholes Reservoir; Adkins et al. 2014). Other prospective colony sites may have no history of Caspian tern nesting, but may be attractive as new colony sites because of the presence of other colonially nesting waterbirds, such as Island 20 and Island 18 in the Richland islands complex on the Columbia River (see *Map 1*).

Periodic monitoring was conducted at all of these prospective colony sites to help evaluate the consequences of management actions implemented on Goose and Crescent islands in 2015 to reduce or eliminate Caspian tern colonies. We sought to assess whether reductions in colony size associated with dissuasion of Caspian tern nesting at Goose and Crescent islands was compensated by commensurate increases in Caspian tern colony size at alternative sites within the Columbia Plateau region, where Caspian terns may continue to consume significant numbers of ESA-listed salmonids.

Periodic aerial surveys were conducted from a fixed-wing aircraft (Cessna 205; Gold Aero Flying Service) to determine the distribution of Caspian terns (both nesting and roosting) along the Columbia River from Bonneville Dam to Chief Joseph Dam, and on the lower Snake River from the mouth of the Clearwater River to the confluence with the Columbia River, as well as at sites off the mid-Columbia and lower Snake rivers that are within tern foraging range (~90 km) of the FCRPS (see *Map 6*). The objective of aerial surveys was to identify all active Caspian tern nesting colonies and large roost sites within the region. Three aerial surveys of the Columbia Plateau region, each lasting two days, were conducted during the 2015 nesting season on the following schedule: (1) on 23-24 April, early in the incubation period, to check for the presence of newly formed colonies; (2) on 15-16 May, late in the incubation period, to determine numbers of breeding pairs, colony area, and habitat types occupied by nesting Caspian terns, as well as identify late-forming colonies; and (3) on 24-25 June, during the peak fledging period, to assess overall nesting success at active Caspian tern colonies. Aerial surveys followed established methods, including reconnaissance surveys to search for new Caspian tern colonies and photographic surveys of sites where nesting Caspian terns were expected to be present. When Caspian terns were observed on the ground on substrate that was potentially suitable for nesting, oblique aerial photography was taken using a digital SLR camera with an image-stabilizing, zoom lens. When in-flight observations of Caspian terns or post-flight digital image inspection revealed a potential Caspian tern breeding colony, ground- or boat-based surveys were conducted to assess the breeding status of Caspian terns using the site.

The frequency of ground-based and boat-based surveys of Caspian tern colony sites identified during aerial surveys varied from several times a week to once a month, depending on location and the amount and type of Caspian tern nesting activity observed at the site. These surveys were conducted at each site throughout the breeding season to determine Caspian tern use of each island (i.e., roosting or nesting), seasonal colony/island attendance, nesting chronology, colony size, and the outcome of any nesting attempts (i.e., nesting success). If Caspian tern nesting occurred at the site, we estimated the number of breeding pairs and colony productivity (average number of young raised per breeding pair) using previously described methods (see *Methods & Analysis: Colony-level Monitoring*).

Geo-referenced high-resolution, vertical aerial photography (2-cm cell size at ground level) was taken by Bergman Photographic at Goose and Crescent islands (*see Methods & Analysis: Colony-*

level Monitoring), as well as at alternative colony sites where aerial surveys or field visits indicated that 40 or more breeding pairs of Caspian terns were nesting. The Bergman aerial photography survey was flown on 20 May and the alternative sites that were photographed included the Blalock islands complex (Anvil, Long, Middle, Southern, Sand, and Straight Six islands) in the mid-Columbia River and Twinning Island in Banks Lake (see *Map 1*).

INTER-COLONY MOVEMENTS

To help assess the extent to which Caspian tern management actions implemented as part of the IAPMP (USACE 2014) and the Caspian Tern Management Plan for the Columbia River Estuary (USFWS 2005, 2006) were successful in relocating Caspian terns to sites outside the Columbia River basin, we resighted Caspian terns previously marked with field-readable leg bands during visits to the Goose Island, Crescent Island, and other nesting and roosting sites used by Caspian terns in the Columbia Plateau region during the 2015 nesting season. Using a comprehensive database containing banding and resighting records for Caspian terns dating back to 2005, we assessed (a) colony connectivity among sites in the Columbia Plateau region, (b) emigration rates of banded individuals from sites in the Columbia Plateau region to sites outside the region, and (c) immigration rates of banded individuals from sites outside the Columbia Plateau region to sites in the region. All of the Caspian tern banding and tagging effort in 2015, and most of the resighting effort in the Columbia Plateau region in 2015 (described below) were funded by the GPUD/PRCC. Furthermore, all banding and resighting efforts performed outside the Columbia Plateau region were conducted as part of related, but separately funded, studies. Satellite tagging results will be summarized in a separate report prepared for the GPUD/PRCC.

In 2015, adult Caspian terns were captured for satellite tagging and banding prior to nest initiation at Crescent Island from 29 March to 2 April and at Goose Island from 10 April to 21 April. Adult Caspian terns were captured using a Netblaster compressed-air net launcher (Wildlife Control Supplies, East Granby, CT). Captured adult terns were banded with a federal numbered metal leg-band and two colored plastic leg-bands on one leg, and a colored plastic leg-band engraved with a unique alphanumeric code on the other leg. This compliment of bands allowed us to individually identify each banded tern from a distance, such that the banding location (colony) and banding year are known. In 2015, 33 and 19 adult Caspian terns were color-banded at Crescent Island and Goose Island, respectively.

Caspian terns that were banded with alphanumeric leg-bands in previous years (2005-2014; BRNW 2015a) and adult Caspian terns banded prior to the 2015 breeding season (*see above*), were resighted using binoculars and spotting scopes up to 7 days per week at Goose Island and up to 4 days/week at the Blalock Islands during the 2015 breeding season. As part of related but separate studies, resighting of previously-banded Caspian terns was also conducted at various sites in the Pacific Coast region during 2015 to evaluate movements of Caspian terns from the Goose Island and Crescent Island colony sites to sites outside the Columbia Plateau region.

Multi-state analysis (Hestbeck et al. 1991, Brownie et al. 1993) in program MARK (White and Burnham 1999) was used to estimate inter-regional movement probabilities of Caspian terns banded as adults during 2005-2014. Movement probabilities were estimated between three regions; the Columbia Plateau (including Blalock Islands, Goose Island, and smaller colonies and loafing sites), the Columbia River estuary (including East Sand Island, Rice Island, and loafing sites), and alternative colony sites (all the Corps-constructed tern islands in interior Oregon and northeastern California). *A priori* models were constructed to evaluate effects of transitions from one region to another and effects of year on movement probabilities. Models that incorporate locations and year effects on resighting probabilities were included in this analysis, which allowed us to calculate unbiased probabilities of inter-regional movement rates despite resighting efforts that varied among locations and years. Akaike's Information Criterion (AIC) adjusted for small samples (AICc) was used to select the best model (Burnham and Anderson 2002) for estimating inter-regional movements. Based on movement probabilities between 2014 and 2015 from the best model, and the numbers of Caspian terns present at a colony in 2014, numbers of terns that moved between colonies from 2014 to 2015 were estimated.

SMOLT PREDATION RATES

The goal of the IAPMP is to reduce Caspian tern predation rates on all ESA-listed salmonid ESUs/DPSs to less than 2% per tern breeding colony per year in the Columbia Plateau region (USACE 2014). Presented here are predicted predation rates for Caspian terns nesting at Goose Island, Crescent Island, and the Blalock Islands in the Columbia Plateau region during 2015; these three colonies were previously identified as posing the greatest risk to the survival of juvenile salmonids out-migrating from the Columbia Plateau region (Lyons et al. 2011a; Lyons et al. 2011b). Estimates of average per capita (per bird) predation rates from previous years (2007-2014), coupled with information on the size of Caspian tern colonies (number of breeding pairs) in the Columbia Plateau region in 2015, were used to predict predation rates by Caspian terns nesting at these three colonies in 2015.

Estimates of per capita predation rates were based on data collected during 2007-2014 on Caspian tern colony size and salmonid predation rates generated from PIT tag recoveries on the colonies at Goose Island (Potholes Reservoir), Crescent Island (McNary Reservoir), and the Blalock Islands (John Day Reservoir). Data collected during 2007-2010 at these sites were previously used by Lyons et al. (2011a, b) to estimate the benefits to each ESA-listed salmonid ESU/DPS of management to reduce the size of Caspian tern colonies. Results from Lyons et al. (2011a, b) were the impetus for Caspian tern management actions identified in the IAPMP. To ensure that the most up-to-date information was used in the present study, the time series analyzed by Lyons et al. (2011a, b) was updated to include colony size and predation rate data collected during 2011-2014, resulting in the aforementioned 8-year dataset (2007-2014). The methods used to predict Caspian tern predation rates in 2015 are the same as those described in BRNW (2014b), and briefly summarized below.

Actual Predation Rates

Estimates of predation rates on ESUs/DPSs of smolts were based on methods previously developed by Evans et al. (2012) and Hostetter et al. (2015). In brief, the number of PIT-tagged smolts available to Caspian terns nesting at each colony was based on the number interrogated (detected alive) passing Lower Monumental Dam (Snake River), Rock Island Dam (Upper Columbia River), or McNary Dam (mid-Columbia River), which ever dam was the nearest upstream dam(s) with adequate PIT tag detection capabilities. PIT-tagged smolts were grouped by ESA-listed ESU/DPS, based on the species, run-type, rearing-type, and origin of each PIT-tagged fish detected (see Evans et al. 2012). The proportion of available PIT-tagged smolts consumed by Caspian terns nesting at each colony was modeled dependently as a three-stage probabilistic process: (1) a PIT-tagged smolt was consumed by a Caspian tern (predation probability), (2) the PIT tag was egested on-colony (deposition probability), and (3) the PIT tag was detected by researchers after the nesting season (detection probability). These events were modeled for each year (2007-2014), each Caspian tern colony (Goose, Crescent, Blalocks), and each ESA-listed salmonid ESU/DPS (Snake River steelhead, Snake River spring/summer Chinook salmon, Snake River fall Chinook salmon, Snake River sockeye salmon, Upper Columbia River steelhead, Upper Columbia River spring Chinook salmon).

We let θ_w represent the probability that a tagged fish is consumed by a Caspian tern in week w, ϕ represent the probability that a consumed fish tag is deposited back on the tern's breeding colony, and ψ_w represent the probability that a tag deposited on the tern colony in week w remains on the colony and is detected. The number of PIT tags recovered on a Caspian tern colony from a given week can therefore be modeled as a binomial process,

$$k_w \sim Binomial(n_w, \theta_w * \phi * \psi_w),$$

where k_w is the number of smolt PIT tags recovered from the number available during each week (n_w). Detection probability (ψ_w) was estimated directly using surveys of PIT tags known to have been deposited on-colony at specific times (i.e. before, during, and after the breeding season; see Evans et al. 2012). We modeled the change in detection probability over time as a logistic function of week,

$$logit(\psi_w) = \alpha + \beta * w,$$

where α is a logit scale regression intercept and β is the logit-scale estimate of change in detection probability for each week. Based on previous investigations of the tag deposition probability for nesting Caspian terns (BRNW 2015a; Hostetter et al. 2015*),* we employed an informative prior (beta [16.20, 6.55]) for ϕ.

We ascribed a hyperdistribution for predation probabilities (θ),

$$logit(\theta_w) \sim Normal(\mu_\theta, \tau_\theta^2)$$

This enables the sharing of information among weeks, while also allowing predation probabilities (θ_w) among weeks to be unique. Noninformative priors are used in the specification of α, β, μ_θ, and τ_θ^2; $\alpha \sim Normal(0, 0.01)$, $\beta \sim Normal(0, 0.01)$, $logit^{-1}(\mu_\theta) \sim Uniform(0,1)$, and $\tau_\theta^2 \sim Uniform(0,20)$. Note that the Normal distribution is specified here by the mean and precision parameters.

Annual consumption totals for PIT-tagged smolts were defined to be the sum of the estimated number of PIT-tagged smolts consumed during each week:

$$Annual\ Consumption = \sum_w (\theta_w * n_w)$$

This estimate of consumption of PIT-tagged smolts was then divided by the total number of PIT-tagged smolts available during that migration year (based on interrogations of PIT-tagged smolts at dams) to estimate the annual predation probability:

$$Annual\ Predation\ Rate = \sum_w (\theta_w * n_w) \Big/ \sum_w (n_w)$$

All predation probability models were implemented using the software JAGS (Plummer 2003) accessed through R version 3.1.3 (R Core Team 2015). We ran three parallel chains for 50,000 iterations each and a burn-in of 5,000 iterations. Chains were thinned by 20 to reduce autocorrelation of successive Markov Chain Monte Carlo samples, resulting in 6,750 saved iterations. Chain convergence was tested using the Gelman-Rubin statistic ($\hat{R}$; Gelman et al. 2004). We report results as posterior medians, as well as 2.5 and 97.5 percentiles, which represent 95% Credibility Intervals (95 CI). Finally, to control for imprecise results that might arise from small sample sizes of interrogated PIT-tagged smolts, estimates of predation were only calculated for ESUs/DPSs when ≥ 500 PIT-tagged smolts were interrogated passing an upstream dam in 2015 (Evans et al. 2012). Predation probabilities ≤ 0.1% are presented without credibility intervals because the upper bounds of the credibility intervals are not greater than 0.1%.

Colony Size

Estimates of Caspian tern colony size (number of breeding pairs) were based on the methods of BRNW (2014a, 2014b, 2015). In brief, colony sizes for Caspian terns nesting on Goose Island, Crescent Island, and the Blalock Islands were determined based on the largest number of incubating Caspian terns counted during aerial and ground surveys conducted near the end of the incubation period (BRNW 2015a; also *Methods & Analysis: Action Effectiveness Monitoring*).

Caspian tern colony size on Goose and Crescent islands in 2015 was strongly influenced by passive and active dissuasion measures as part of implementation of the IAPMP; no (zero) breeding pairs laid and hatched eggs on Crescent Island and only two breeding pairs laid and hatched eggs on Goose Island (see *Results & Discussion: Colony-level Monitoring*). Caspian terns on Goose Island, however, made several additional nesting attempts that were thwarted by researchers collecting the egg soon after it was laid; at least 39 additional Caspian tern nests were initiated (classified as a nest scrape containing an egg) from 21 April to 19 June, 2015. Adult Caspian terns were also routinely observed on Goose Island prior to and following hazing, with an average weekly count of 28 adults (range = 7 to 80 adults) observed during the smolt out-migration period for steelhead and yearling Chinook salmon from the Upper Columbia River, from 13 April to 14 June, 2015. Given the number and duration of Caspian tern nesting attempts and the daily presence of adult Caspian terns on Goose Island, it seems likely that the actual predation rates of Goose Island Caspian terns on salmonid smolts from the Upper Columbia River represented much more than just that of the two breeding pairs that successfully hatched eggs on Goose Island in 2015. Consequently, for the purpose of estimating predicted predation rates in 2015, Caspian tern colony size on Goose Island was considered to be between 14 and 39 breeding pairs in 2015. There were no (zero) Caspian tern nests initiated and no Caspian tern adults observed on Crescent Island during the smolt out-migration period in 2015, so for this colony, zero breeding pairs was the appropriate measure of colony size.

Per Capita Predation Rates

The annual per capita predation probability for each Caspian tern colony and each salmonid ESU/DPS in year, *y*, was calculated by dividing the annual predation probability by the peak colony size from that year:

$$Annual\ Per\ Capita\ Predation\ Rate_y = {\sum_w (\theta_{wy} * n_{wy}) / \sum_w (n_{wy})} \Big/ {C_y}$$

where C_y is the peak colony size in year, *y*, as previously defined.

We calculated a per capita predation probability for each colony and each salmonid ESU/DPS in 2015 using the arithmetic average of the annual per capita predation rates in 2007-2014. We built 95% CIs by averaging random samples of per capita predation rates generated from the posterior distributions calculated previously.

Predicted Predation Rates

In order to estimate predation probabilities in 2015 based on measures of colony size alone, we used a Markov Chain Monte Carlo process to generate samples from a posterior predictive distribution based on random draws from the posterior distribution of the average annual per capita predation rate. Predicted per capita predation rate estimates for each salmonid ESU/DPS were then generated for (1) the Goose, Crescent, and Blalock islands Caspian tern colonies in 2015 and for (2) various hypothetical Caspian tern colony sizes ranging from 0 to 700 terns at each of these three colony sites.

Key assumptions and caveats that should be considered when using only data on Caspian tern colony size to predict salmonid ESU/DPS-specific predation rates include:

- Per capita predation rates do not assume or otherwise rely on a mathematical relationship between annual measures of colony size and predation rates.

- The statistical model used to generate per capita predation rates assumes independence among colony size, smolt abundance, and predation rate.

- Statistical inference of the model should be limited to those colony sizes and smolt abundances observed during 2007-2014; conditions outside of these limits may influence predation probabilities to an unknown degree.

- The prior distribution associated with on-colony tag deposition rates has a large impact on the precision of predation rate credibility intervals. Any unidentified variation in past tag deposition rates or significant deviation in future tag deposition rates may bias predation rate estimates and credibility bounds to an unknown degree.

- The accuracy of Caspian tern colony counts depended on the intensity and frequency of colony monitoring in each year, levels that varied by colony location and year. Similarly, there is no measure of uncertainty associated with estimates of colony size, but presumably some error is associated with these estimates.

- Smolt condition, run-timing, smolt abundance, river discharge, and turbidity have all been linked to variation in predation rates on smolts (Hostetter et al. 2012). Thus, changes to biotic and abiotic conditions in the Snake and Columbia rivers during 2015 may influence Caspian tern predation rates on salmonid smolts.

- Estimates of predation rates presented here are colony-specific; extrapolation to other geographic locations is beyond the scope of the analysis.

RESULTS & DISCUSSION

PASSIVE NEST DISSUASION

Goose Island

In 2015 as in 2014, the installed passive dissuasion materials were successful in deterring Caspian terns from establishing a nesting colony on Goose Island. Only two breeding pairs of Caspian terns were successful in producing young, both nests were initiated in isolation from other Caspian terns attempting to breed elsewhere on the island. The two nests were discovered under passive dissuasion materials near the former Caspian tern colony site on Goose Island (see *Map 2*). Though a third Caspian tern was observed nesting within the passive dissuasion materials on Goose Island, the one egg observed in the nest was depredated by a gull shortly after it was discovered. Notably, all three Caspian tern nests initiated within the passive dissuasion were located near steep terrain, which may have allowed a more direct flight path for terns to and from their nest without contacting ropes and flagging. During post-season inspections of the passive dissuasion materials on Goose Island, no apparent differences were found in the materials or installation of those materials in areas with and without Caspian tern nests.

These results confirmed that passive nest dissuasion (i.e. ropes and flagging suspended above the ground), when used in concert with human hazing, provide an effective and targeted means to deter Caspian terns from nesting in areas of suitable habitat. The results also confirmed findings from 2014, that passive nest dissuasion had little deterrent effect on non-target species (i.e. California gulls, ring-billed gulls, and Canada geese) on Goose Island, which nested in areas covered with passive nest dissuasion. Similar to 2014, gulls nested within both single and double layers of passive nest dissuasion indiscriminately (see *Map 2* and *Map 7*). Finally, the efficacy of the two owl models that were used on East Rocks and Northeast Rocks as passive nest deterrents could not be determined because they were used in concert with ropes and flagging on the East Rocks, and during a period of increasing reservoir levels that ultimately inundated both potential nesting sites.

Periodic inspections of passive nest dissuasion materials deployed at Goose Island have confirmed a projected multi-year lifespan of the components, with the exception of the flagging. Although wear of the polypropylene ropes was detected, virtually no repairs or replacement of materials deployed in 2014 were necessary. A cost effective and semi-permanent alternative to the flagging (barricade tape) that has been used in 2014-2015 has, however, not yet been identified. As such, all flagging material was removed from Goose Island following the 2015 breeding season and needs to be replaced again prior to the 2016 breeding season. A small amount of additional passive dissuasion should be deployed prior to the 2016 breeding season to eliminate marginal nesting habitat at or below the high water line, where most of the Caspian tern eggs were laid and either collected or depredated by gulls during the 2015 nesting season (see *Results & Discussion: Active Nest Dissuasion*).

In summary, Caspian tern use of Goose Island was strongly influenced by placement of passive nest dissuasion materials in 2015. While two pairs of Caspian terns nested successfully in areas where passive dissuasion (ropes and flagging) was installed, counts of adult Caspian terns and the number of Caspian tern eggs laid were substantially higher in areas of Goose Island where passive nest dissuasion materials were not used (see *Results & Discussion: Active Nest Dissuasion*).

Crescent Island

The installation of passive nest dissuasion materials was successful in deterring Caspian terns from establishing a breeding colony on Crescent Island in 2015. Once passive dissuasion was fully installed, no Caspian terns landed on any portion of the island, and no Caspian tern nests were initiated or Caspian tern eggs laid on Crescent Island in 2015. Passive nest dissuasion had little deterrent effect on non-target species (i.e., California gulls, ring-billed gulls, and Canada geese) on Crescent Island, evidenced by the presence of gulls and the nesting of Canada geese within each of the three types of passive dissuasion. Active hazing efforts were ultimately responsible for preventing the formation of a gull breeding colony on Crescent Island in 2015 (see *Results & Discussion: Active Nest Dissuasion*).

In 2015, significant growth of non-native invasive plants was observed in all open areas on Crescent Island, both within and outside the passive nest dissuasion areas (see *Map 8*). Vegetation growth was more pronounced along the perimeter of the island, and less pronounced across the former Caspian tern colony area. In general, the invasive plant species found across the entire island were the same non-native annual herb species identified in the willow test plot in 2014: *Kochia scoparia* and *Atriplex rosea*.

Researchers tested various types of fence materials prior to purchase and installation. We selected a cost-effective alternative to woven landscape fabric, which has been used extensively as a nesting deterrent at the Caspian tern colony on East Sand Island in the Columbia River estuary (BRNW 2015a). The material selected for use on Crescent Island was a 90% knit privacy screen that was custom finished with reinforced and grommeted edges, which allowed for efficient installation and future removal. Additionally, selecting a knit material reduced the likelihood of material degradation at attachment points, which ultimately has resulted in material failure of woven landscape cloth when deployed in similar applications. Periodic inspections of the passive dissuasion matrix confirmed the resiliency of all materials. A cost-effective and semi-permanent alternative to the flagging (barricade tape) that was used in 2014 and 2015 has, however, not yet been identified. Consequently, all flagging material was removed from Crescent Island in July 2015 and will need to be replaced prior to the 2016 nesting season.

The use of woody debris as a passive nesting deterrent produced mixed results in 2015. Large branches from existing dead trees were cut and scattered successfully. Branches cut from live Russian olive trees, however, were removed and consumed by resident North American beavers (*Castor canadensis)* within a few weeks of their deployment. Resource managers may consider fencing areas containing freshly cut Russian Olive as a passive nest dissuasion technique.

In summary, Caspian tern use of Crescent Island was strongly influenced by placement of passive nest dissuasion materials in 2015. At no time following deployment were Caspian terns observed attempting to land in or near passive dissuasion, regardless of its type (i.e., fences, rope and flagging, woody debris). The more persistent attempts by Caspian terns to nest on Goose Island in 2015 , compared to Crescent Island, can be ascribed to one or more of the following: (1) the knit privacy screen fences used over much of Crescent Island were a more effective deterrent for nesting Caspian terns than the ropes, stakes, and flagging that were used on Goose Island; (2) gulls did not form a colony on Crescent Island, whereas a large gull colony formed on Goose Island, providing social attraction for prospecting Caspian terns; and (3) suitable alternative nesting sites for Caspian terns were more available in the vicinity of Crescent Island than in the vicinity of Goose Island.

Willow Plot – Vegetation growth within the willow test plot was abundant during the 2014 and 2015 nesting seasons (see *Map 9*), and included three primary species. In addition to growth of the planted willow stems, two non-native annual herb species (*Kochia scoparia* and *Atriplex rosea*) grew abundantly in the test plot during both 2014 and 2015. Mean lengths of the tallest sprouted live shoot from each planted willow stem increased from 148 cm in 2014 to 166 cm in 2015.

Overall, the performance of individual planted willow stems declined considerably between 2014 and 2015. For 255 cuttings planted in late February 2014, 233 (91%) were confirmed to have sprouted and 216 (85%) were considered alive in August of the first growing season. Vigor scores indicated that 55% of planted stems were growing and appeared healthy (vigor = 2 or 3) at the end of the first growing year. During inspection of the test plot in March 2015, before many planted stems were showing visible signs of growth, 209 (82%) were considered alive and 49% of stems had vigor scores indicating they were healthy (vigor = 2 or 3; *Table 2*). After the second growing year, just 31% of individual stems were considered alive, and the proportion of stems with a vigor score of 2 or 3 fell to just 23%. Thus, after two growing years, 77% of planted stems were described as in decline or dead (vigor = 1 or 0, respectively). We found that evaluation of willow condition based on sprouting (presence of new stems) was difficult after the second growing season because 2014 and 2015 growth could not always be distinguished on the plants, particularly plants that were dead by fall 2015. For this reason, we did not utilize sprouting data to evaluate willow condition after the second growing season.

Overall performance of the willow stem plantings was better when multiple stems were planted per hole and when success was measured at the level of the planting hole. After the first growing year, for the 75 planted holes, 72 (96%) had one or more sprouted stems and 68 (91%) had at least one live stem. The number of planted holes with at least one live stem dropped to 48 (64%) by the end of the second growing year. Data from the individual planted stem with the most vigorous growth in each planting hole indicated that 63 (84%) of the planting holes contained a healthy willow (vigor = 2 or 3) after the first growing year and 42 (56%) of the holes contained a healthy willow after two growing years. Average willow leader length was 184 cm in 2014 and 168 cm in 2015, when data were restricted to planted stems with the highest vigor score in each planting hole.

While the success in producing a healthy, growing willow in a planting hole was increased by using multiple stems per hole, survival of at least one stem in all holes for each of the five planting treatments was not observed after the second growing season. Proportions of planted holes with a live willow was 100% for the three treatments where 5 stems were planted per hole in August 2014, but dropped to 47 (93%) after the second growing season (*Table 2*). Similarly, vigor scores for the 45 planting holes with five stems indicated that apparently healthy stems (vigor = 2 or 3) dropped from 44 (98%) after one growing season to just 30 (67%) after the second growing season.

The single stem planting treatments also experienced declines in survival and vigor during the second growing season. After first season survival of 73% and 80% for the soaked and not soaked stems, survival dropped to 40% and 53%, respectively, by the end of the second growing season (*Table 2*). While 63% of the single stem treatments were scored as healthy (vigor = 2 or 3) after the first growing season, just 40% were scored as healthy after the second growing season.

After the first growing season, planting holes with a single stem had lower mean leader lengths (163 cm and 171 cm) and smaller stem diameters (8.6 mm and 8.9 mm) in comparison to estimates from the five-stem planting treatments (leader lengths: 177 cm, 200 cm, and 209 cm; stem diameters: 7.9 mm, 9.5 mm, 9.6 mm; *Table 2*). After the second growing year, however, planting holes with single stems had mean leader lengths (168 cm and 182 cm) and stem diameters (9.3 mm and 11.6 mm) that were not appreciably different from those of the five-stem planting treatments (leader lengths: 150 cm, 161 cm, and 182 cm; stem diameters: 8.4 mm, 10.0 mm, 10.6 mm; *Table 2*). The difference between years may be the due to mortality of some large willows measured in 2014. Additionally, in late summer 2015 we found that shorter shrubbier willows were the most vigorous willows in some holes. This led to measurement of leader lengths and diameters of willows in 2015 that were less likely to be the tallest willows in the planting holes with five stems.

After two growing seasons, it was not clear from the data collected that willow plantings with soaked stem treatments performed better than plantings of stems that were not soaked. Data from paired treatments showed a conflicting pattern. Point estimates of mean leader length for soaked stems were longer after one growing season, but only the multiple stem treatments were longer after 2 growing seasons (*Table 2*). After two growing seasons, survival was markedly higher (87%) per planting hole for the five-stem treatment using soaked stems compared to five-stem plantings where stems were not soaked (47%). Survival of the single stem plantings that were not soaked, however, was higher (53%) than survival of the single stem plantings that were soaked (40%). Average leader diameter and vigor scores were similar or slightly skewed towards better performance in the unsoaked treatments after one growing season. However, more single stem plantings that were not soaked and more five-stem plantings that were soaked were healthy after two years (*Table 2*). All willow stems collected from Crescent Island were soaked (no paired treatment) and had 100% survival after one growing season and 93% survival after two growing seasons, but mean leader length and diameter were low in comparison to the five-stem plantings of stems from Two Rivers Park. It should be noted, however, that the performance of willow stems from Crescent Island may have been affected by an apparent lower vigor, smaller cutting size, and shorter soaking time (Hoag 2014).

For the planting project described in the IAPMP, it was most useful to evaluate the success of willow plantings based on the growth and survival of at least one willow stem per planting hole. Based on the planting conditions on Crescent Island, Chris Hoag predicted a survival rate of about 65% for willows at the level of the planting hole after the first growing season. Therefore, confirmation of live willow stems in 73–100% of the planting holes in August 2014 for the five treatments represented unexpectedly positive results after the first growing season. Survival over the second growing season dropped to 40–93%, with soaked single-stem plantings from

Two Rivers having the lowest survival and soaked five-stem plantings of stems from Crescent Island having the highest survival. In combination, factors that appeared to improve success rate per willow planting hole were soaking of the willow stems before planting and using multiple stems per planting hole. After two growing seasons, the percent of planting holes with at least one live willow was 88–93% for planting holes with five soaked stems, whereas only 40–53% of planting holes with single stems or stems that were not soaked contained a live willow (*Table 2*).

Treatments with multiple stems per planting hole were advised by Chris Hoag on the premise that the most labor intensive and potentially costly aspect of planting a willow cutting is digging the hole. By increasing the number of stems in a planting hole, we increased the probability that at least one cutting would grow and survive. In addition, using multiple cuttings may deter destruction of a planting because beaver will selectively harvest stems to keep a stand from dying out (C. Hoag, pers. comm.). Thus, at a large scale, where fencing protection or complete protection against beaver damage may not be feasible, plantings with multiple cuttings may provide an additional hedge against total loss of willow at individual planting holes.

After the second growing season, we inspected each willow cutting for signs of damage from mammals or birds (insect damage is described elsewhere), but none were found. Fresh beaver sign was observed at several locations on Crescent Island and gnawing damage to established local willows was evident prior to the test planting in February 2014. However, the exclusion fence installed around the willow test plot was effective in protecting the planted willows from beaver or other large gnawing mammals that may have been present over the two growing years. No gulls nested on Crescent Island in 2015, but California gulls were allowed to access the test plot in 2014 and 10 pairs nested inside the exclusion fence. Gulls were allowed to access the test plot by design because excluding gulls from an island-wide willow planting in the implementation phase for this potential management approach would likely not be feasible. During 2014, gulls were observed in the willow test plot throughout the growing season and observers confirmed that gulls occasionally picked at vegetation growing in the test plot area, but there was no indication that this behavior limited the growth or survival of willows, *Kochia,* or *Atriplex* in the test plot.

We found that deformities caused by insect damage or water stress were common on most willows after the second growing season. For the 255 planted cuttings, insect damage was recorded for 66 cuttings and water stress was recorded for 128 cuttings; 6 cuttings were recorded as showing signs of both types of deformity. For live willows with signs of current or recent insect activity, assigning insects as the source of deformity was obvious and took the form of stem scarring, cracking, and breakage. We collected one representative insect-damaged stem and confirmed that it contained the grub of a western willow clearwing (*Synanthedon albicornis*; W. Gerth, pers. comm.). Water stress was assigned to willows with mostly brown and yellow leaves, typically when a plant had recent growth but no signs of insect damage. However, for cuttings with no recent growth, but with dry stems and leaves, while water stress was generally assigned to these stems, actual cause of poor plant condition may have been a combination of insect activity, lack of available water, and other factors. Thus, it was difficult to attribute plant condition, especially for dead willows, to a definitive cause.

The prevalence of insect damage to willows in the test plot appeared to increase between the first and second growing seasons. In late summer 2014, damage from an unidentified insect was noted for 10 cuttings, caused swelling and scarring on stems, but no damage to willow leaves was reported. Thus, insect damage did not appear to be a significant limiting factor for growth and survival of willow plantings during the 2014 growing season. After the second growing season, however, we inspected each willow cutting for deformities and insect damage was observed on 66 cuttings, including 59 of 78 (76%) cuttings that were alive. In addition to stem swelling, scars, and splitting of willows, we observed a regular occurrence of shoots that were broken at the location of insect-induced deformities or with leaves that were yellow or brown above the insect-induced deformity. Although the incidence of insect-induced deformities was not quantified after the 2014 growing season, researchers who collected data in both years found that insect damage to willows was more prevalent across the test plot in August 2015.

During inspection for deformities, field personnel recorded many cuttings with signs of water stress, but again we found it difficult to interpret these data. Water stress was recorded for 102 of 255 (41%) cuttings in March 2015, and the incidence increased to 128 cuttings (50%) by August 2015. While water stress almost certainly contributed to reduced vigor and mortality of some willow cuttings, it was difficult to independently assess the impact of water stress as a limiting factor. The high reported incidence of water stress was in part due to sprouted willows that died (virtually always dry) being coded for water stress as a deformity. Differences in the incidence of water stress between March and August 2015 were confounded by the lack of leaves on willows during March (before the growing season), and therefore water stress deformities could only be assessed from willow stems. In August, yellow and brown leaves were a clearer indication of water stress for most willows.

Despite some challenges in the interpretation of data on willow deformities, signs of water stress appeared to be less prevalent than insect-induced deformities based on the records for the most vigorous cutting in each planting hole (*Table 2*). After two growing seasons, water stress was reported for 7 – 27% of planting holes, whereas insect deformities were reported for 40 – 67% of the most vigorous willow stems from each planting treatment. On Crescent Island, it would be difficult to attribute decline or death of a willow cutting to water stress without information on McNary Reservoir water levels which strongly influence the water table on Crescent Island. Insect damage is fairly common in native willow communities, especially those that have been stressed by drought (C. Hoag, pers. comm.). Thus, it is likely that these limiting factors worked in concert to cause the decline and mortality of willow plantings in the test plot.

Evaluation of the willow test plot after two growing seasons suggested that the combination of soaking and increasing the number of willow cuttings per planting hole increased the proportion of holes that contained at least one live willow. Two of the three treatments that involved planting five willow cuttings per planting hole (both soaked) experienced greater than

80% survival at the level of the planting hole. In contrast, only 47% of willow plantings that involved planting five cuttings that were not soaked contained a live willow stem in August 2015.

Our data suggest that the source of willow cuttings used for planting influenced the growth and survival within several treatments. After each growing season, leader lengths and diameters were greater for the treatments using five cuttings per planting hole of cuttings collected from Two Rivers Park, as compared with the Crescent Island treatment. We attribute this growth differential to the quality of source plants; Crescent Island willows were scarcer and smaller, in part due to beaver browsing, than their counterparts at Two Rivers Park. Thus the size and vigor of cuttings acquired on Crescent Island likely contributed to reduced leader growth following planting in the Crescent Island test plot. Nevertheless, cuttings from Crescent Island, while smaller after each growing season than their Two Rivers Park counterparts, had the highest survival of all treatments over the 2 years. This may reflect local adaptation of the Crescent Island cuttings to the conditions on the island, reflected in lower allocation to growth and higher survival.

After reviewing our results after two growing seasons, C. Hoag (pers. comm.) indicated that a major contributor to high survival in a willow planting project like Crescent Island is the source of willow cuttings. For most such projects, insect damage and high mortality rates among cuttings can be tied to the cutting source. C. Hoag (pers. comm.) has found that a willow source with good water availability creates more vigorous cuttings with less insect and disease problems. As such, C. Hoag and associates (pers. comm.) advocate contracting with a local nursery to grow the needed specimens from local ecotypes. Local ecotypes are very important in order to maximize fitness of plants. A nursery can water and fertilize the mother plants, which leads to a guaranteed source with high vigor. The nursery can also spray the mother plants to significantly reduce insect infestations. These methods increase the survival of willow cuttings following planting and enhance success rates of planting projects over long term (C. Hoag, pers. comm.).

Although we saw no consistent or distinct differences in the growth, vigor, or survival of willow cuttings based on the soaking treatment, soaking of cuttings was used in three of the five treatments, including the two treatments with the highest survival rates after two growing seasons. The lack of a clear soaking effect was probably because reservoir water levels were high when the willows were planted, which was before willows started to sprout. While actual reservoir levels were not recorded, it was clear that they were relatively high when willow cuttings were planted; the cuttings in all holes were planted in at least 15 inches of standing water, which may have mitigated the effect of not soaking cuttings for some treatments.

Although there was abundant growth of *Kochia* and *Atriplex* in the willow test plot, these invasive species are not typically significant competitors with most willow species (C. Hoag, pers. comm.). Tree willows develop a crown and often shade and eliminate nearby weeds, but *Salix exigua* is a shrub that commonly grows only to heights of about 6-8 feet under good conditions. While *S. exigua* is less capable of shading out invasive weeds than other willows, it is a creeping willow with a large root system and will typically outcompete invasive weeds by providing no space for them to grow. We did not observe vigorous willow growth in the test plot that led to crowding out of the non-native species, but we did see increased mean height in willow leaders and decreased mean heights of *Kochia* and *Atriplex* from August 2014 to August 2015. This trend was positive for meeting project goals using willow plantings and was likely related, at least in part, to changes in conditions between the two years of the study.

Over the two growing seasons, *Kochia* and *Atriplex* plants that grew in the willow test plot were considerably larger than plants of these two species outside the test plot. These non-native plants were clipped and discarded outside the test plot fence after each growing season to collect data on the willow plantings. Removal of these invasives may have influenced willow growth and survival through release or exposure, but assessing potential impacts of invasive plant removal was beyond the scope of this project. Likewise, it is not clear how leaving the plants in place might have affected long-term willow growth and survival. Both *Kochia* and *Atriplex* are annuals, so continued growth of invasives during the second growing season would not be a factor. New plants would sprout from seed produced during prior growing seasons. If left in place, the density of live or dead plant material after the first growing season could have played a role in subsequent willow growth. For example, with such dense vegetative cover in the willow test plot, voles (*Microtus* spp.) could become a problem. Dense cover around the base of willows provides habitat for voles and they can easily girdle small-diameter willow stems. Although voles were not noted on Crescent Island, they could be present. Because both *Kochia* and *Atriplex* are annual tumble weeds, they could be blown away by the wind if the willows and/or the exclusion fencing did not trap dead plants in place. Additional research would be needed to determine how *Kochia* and *Atriplex* may affect the growth and survival of willows planted on Crescent Island for avian management, but release and vigorous response of non-native vegetation may be possible through modification of willow planting techniques.

We speculate that the combination of loosening the substrate by drilling holes and watering the holes with a large water pump that also wetted a large area around the willow plot, both inside and outside the exclosure fence, created suitable conditions for non-native vegetation to germinate and grow, particularly at each planting hole. Vigorous growth of *Kochia* and *Atriplex* at the planting holes, compared to the surrounding area, suggests that drilling out and refilling the planting holes resulted in seed germination and release of these non-native species. Further research would be needed to prove this hypothesis and to come up with a procedure that would reduce the number of non-target species that become established in willow planting holes, if deemed necessary to improve willow growth and survival.

In summary, results from the willow plantings in the test plot indicate that planting native vegetation is a viable option for reducing or eliminating potential nesting habitat for Caspian terns on Crescent Island. After two growing seasons, growth and survival of the native willows planted in the test plot was considered moderate, but the combined growth of willows and non-native vegetation was deemed adequate to preclude Caspian terns from nesting in the test plot. In both 2014 and 2015, willows and non-native annuals covered the entire test plot area by June. Our planting methods appeared to stimulate germination and growth of non-native annuals, and our use of multiple willow stems per hole and soaking stems prior to planting increased the numbers of planting holes with live willows for most treatments. Based on these findings, we recommend that multiple, soaked cuttings from a local eco-type of willow be planted per planting hole during the implementation phase of vegetation planting to limit Caspian tern nesting habitat.

ACTIVE NEST DISSUASION

Goose Island

Active and passive nest dissuasion efforts for Caspian terns on Goose Island were successful in preventing all but two breeding pairs of Caspian terns from nesting on Goose Island or the surrounding small rocky islets. These two breeding pairs nested near the former Caspian tern colony site on Goose Island under passive nest dissuasion materials (see *Map 2* and *Map 4*). It was not possible to haze these two breeding pairs from their nests, or to collect their eggs (under permit), due to the high probability of causing gull nest failure for gulls nesting nearby. Incidental gull egg take associated with Caspian tern nest dissuasion activities was not permitted under the applicable Caspian tern egg take permit issued by the USFWS for this management effort, or the BMPs (see *Appendix A*).

Similar to what was observed in 2014, prospecting California and ring-billed gulls took flight briefly and re-landed within 10 m of the hazer in response to island walk-throughs conducted during daylight hours. Early in the season, island walk-throughs were more effective in displacing gulls when conducted during the evening. Gulls actively hazed near evening civil twilight would typically abandon Goose Island overnight, return to the island at sunrise, and remain on the island throughout the day, consistent with reports in the literature (Ryder 1993). Increasing the duration of morning and evening hazing sessions to three hours each beginning on 20 March did not reduce the numbers of gulls present on the island or delay the onset of gull nesting at Goose Island. As in 2014, gulls habituated to human presence quickly, even when the frequency of active hazing was increased. The first gull egg discovered on Goose Island during the 2015 season was found on 14 April on the main portion of Goose Island, slightly later than the first gull egg discovered in 2014 (9 April; BRNW 2014b). By 18 April 2015, gull nests containing one or more eggs were so numerous and widely distributed across Goose Island that field personnel were unable to conduct island walk-throughs any longer, for reasons described above (also see *Appendix A: Best Management Practices*). No documented loss of gull eggs due to hazing occurred during the 2015 breeding season.

Prior to the initiation of egg-laying by gulls, we tried using a peregrine falcon kite during active hazing sessions; this technique was initially highly effective in flushing both gulls and Caspian terns from Goose Island. The first time the peregrine falcon kite was flown (25 March), all gulls (ca. 3,000) flushed from the island for nearly two hours. Within days, however, flying the peregrine falcon kite resulted in all gulls flushing from the island only to re-land within 30 minutes. Researchers also tried throwing sticks in the air concurrent with flying the falcon kite in an attempt to better simulate a falcon attack; this initially increased the time before flushed gulls returned to the island. Similarly, though, gulls began habituating to any combination of these two techniques within a few days. This was reflected in both the length of time it took for gulls to re-land on the island and the number of gulls that re-landed after the hazing event. Use of the peregrine falcon kite was discontinued on 4 April. Although gulls eventually habituated to the falcon kite, use of the kite proved to be more effective than walk-throughs alone during the early stages of the breeding season.

During the 22 weeks when active hazing efforts were quantified, daily effort ranged from a cumulative duration of 34 min to 471 min, and the cumulative weekly hazing duration ranged from 240 min to 3,295 min (*Table 3*). The average number of Caspian terns counted each week by location on the island indicated that the highest area of use during the nest initiation period (mid-April to mid-June) was the southwest tip of Goose Island (see *Map 4*; *Table 3*).

From late May through July, the reservoir water level measured at Goose Island decreased nearly 10.5 feet, exposing large areas of open shoreline habitat around Goose Island and the nearby rocky islets. Caspian terns began utilizing this open habitat, especially on the southeast and southwest shorelines of the main island (see *Map 4*; *Table 3*). On 21 June, as declining reservoir water levels uncovered new open habitat and numbers of prospecting Caspian terns increased in these areas, researchers initiated walk-throughs along the island's southern shoreline to reduce Caspian tern use of that area.

Despite active and passive nest dissuasion efforts on Goose Island in 2015, from 21 April to 19 June a total of 43 Caspian tern eggs were laid during 39 separate Caspian tern nest attempts (Figure 1). These counts are minimums because a few Caspian tern nesting attempts and Caspian tern eggs laid on Goose Island may have gone undetected before gulls depredated the egg. Most Caspian tern nesting attempts (n = 30 or 77%) were initiated near the shoreline on the south side of the west lobe of Goose Island, predominately on the southwest tip of the island (see *Map 4*; *Table 3*). Smaller numbers of Caspian tern nests were initiated at other locations: one on Northwest Rocks, two on the south gravel bar of the main island, one in the northwest corner of the main island near the entrance to the tunnel leading to the observation blind, one on the north beach (isthmus) near the researcher camp, one on East Rocks, and three under passive dissuasion materials near the former colony area on Goose Island (see *Map 4*; *Table 3*). Of the 43 Caspian tern eggs that were confirmed in tern nests on Goose Island, 17 eggs were collected under permit, 23 eggs were depredated by gulls when attending Caspian terns were hazed from their nest, and 3 eggs hatched and produced chicks (*Figure 1*; *Table 4*). The three chicks that hatched on Goose Island were in two separate nests, both initiated under passive dissuasion near the former Caspian tern colony area on the west lobe. Two Caspian tern chicks, one from each nest, were raised and fledged.

In accordance with the federal depredation permit, all eggs collected from Caspian tern nests on Goose Island were offered to R.C. Faucett, Ornithology Collection Manager at the Burke Museum, University of Washington. The eggs were delivered to the Burke Museum on 15 August.

In summary, hazing efforts were successful in preventing the formation of a Caspian tern colony on or near Goose Island in 2015. To achieve this objective, however, nearly continuous monitoring and hazing efforts were required during much of the Caspian tern breeding season (April – July). Despite these efforts, 43 Caspian tern eggs were laid on or near Goose Island in 2015, with only three producing young (*Figure 1*). Restrictions on disturbing nesting gulls and Canada geese will continue to limit the efficacy of active nest dissuasion techniques employed at Goose Island to prevent Caspian tern from nesting on the island, as these restrictions severely limit access to the areas of the island where Caspian terns are prospecting for nest sites.

Crescent Island

The passive nest dissuasion techniques deployed on Crescent Island, in concert with active hazing, were successful in preventing breeding colony formation by Caspian terns, ring-billed gulls, and California gulls in 2015. No active hazing of Caspian terns was required on Crescent Island, as no Caspian terns were observed on Crescent Island after passive nest dissuasion materials were fully installed. Moreover, no nesting attempts or eggs laid by gulls were detected on Crescent Island in 2015. The first breeding behaviors by gulls observed on Crescent Island were limited to the early stages of nest building by three birds observed the evening of 24 March. No additional nesting behavior by gulls was observed until the morning of 4 April, when a maximum of 60 early stage nests were observed. After 4 April, active hazing prevented gulls from having adequate time to create nest scrapes and build nests. No egg-laying by gulls, either California or ring-billed gulls, was recorded on Crescent Island during the 2015 breeding season.

During the 20 weeks when active hazing efforts were conducted on Crescent Island, the average duration of daily effort ranged from 0 min to 257 min, and total weekly hazing times ranged from 0 min to 1,802 min (*Table 5*). Active hazing efforts were highly variable throughout the nesting season as researchers adapted to changes in the type, frequency, and intensity of gull nest prospecting behavior. Three primary gull behaviors were used to trigger active hazing of gulls on or near Crescent Island: (1) landing in and occupying the former gull colony area, (2) rafting in the water near the shoreline of Crescent Island, and (3) prolonged hovering over the island. Gull prospecting activity on Crescent Island peaked in late March, when ca. 2,100 gulls were observed roosting on the former colony area prior to hazing. Adaptive hazing techniques were successful in preventing gulls from landing on Crescent Island for much of the remainder of the season, however. Beginning on 4 April, virtually no gulls were permitted to land on Crescent Island for the remainder of the breeding season. During the first few weeks in April, gulls continued to show an interest in nesting on Crescent Island, with more than 5,000 individuals observed rafting in the water near the island. During much of April, we observed frequent hovering behavior by gulls over the island (up to 400 individuals); however, active hazing prevented hovering gulls from landing on the island.

Gull activity at Crescent Island began waning in early May, shortly after the first observation of large numbers of gulls (ca. 1,300) prospecting on nearby Badger Island on 28 April. Badger Island is located on the mid-Columbia River one kilometer up-river from Crescent Island (see

Map 1). During a boat survey of Badger Island on 7 May ca. 2,200 gulls were counted along the western shoreline of the island, several of which were observed copulating. Nesting by gulls in the interior of the Badger Island was confirmed during an aerial survey on 15 May. Attended gull nests (ca. 650) were first confirmed by field observers on 19 May and gull nestlings were first confirmed on Badger Island on 13 June. These findings suggest that many of the gulls that formerly nested on Crescent Island formed a new breeding colony on Badger Island, adjacent to and within areas of the island where American white pelicans have been nesting for the last 17 years.

In summary, nesting by Caspian terns on Crescent Island was prevented in 2015 by the combination of passive and active nest dissuasion techniques implemented on the island. A likely factor that contributed to the absence of nesting Caspian terns on Crescent Island was the successful dissuasion of all gull nesting on Crescent Island in 2015; nesting gulls provides strong social attraction for prospecting Caspian terns and other colonial nesting associates of gulls. Unlike at Goose Island, where gull nesting could not be prevented using the authorized passive and active nest dissuasion techniques, prospecting gulls at Crescent Island never habituated to the combination of passive and active dissuasion techniques that were implemented. Additionally, Badger Island provided alternative nesting habitat in close proximity for prospecting gulls subject to nest dissuasion measures implemented at Crescent Island.

ACTION EFFECTIVENESS MONITORING

Goose Island

The passive and active nest dissuasion techniques used on Goose Island in 2015 were successful in preventing all but two breeding pairs of Caspian terns from nesting on the island (see *Results & Discussion: Active Nest Dissuasion*). Caspian tern use of Goose Island for roosting and nesting was primarily limited to areas at or near the shoreline where passive nest dissuasion had not been deployed. Active nest dissuasion (hazing), collection of Caspian tern eggs that were discovered, and high rates of gull depredation on Caspian tern eggs soon after laying were collectively successful in preventing the formation of a Caspian tern colony anywhere on Goose Island or the surrounding small rocky islets in 2015.

Average weekly attendance by Caspian terns on Goose Island and nearby islets was generally lower in 2015 compared to the previous year (*Figure 2*), likely associated with the expansion of passive nest dissuasion efforts in 2015 to include the rocky islets surrounding Goose Island. In 2014, the first year of implementation for the IAPMP at Goose Island, we estimated that a total of 159 breeding pairs of Caspian terns nested on Goose Island and the surrounding islets, which was a sizeable reduction in colony size compared to previous years (*Figure 3*). Of the total number of breeding pairs of Caspian terns on or near Goose Island in 2014, all but three pairs nested on a nearby rocky islet (Northwest Rocks), where nest dissuasion techniques were not implemented (BRNW 2014b). In 2015, only one pair of Caspian terns laid an egg on Northwest Rocks, and no successful nesting by Caspian terns occurred there. The number of breeding pairs of Caspian terns that successfully nested on Goose Island and nearby islets was just two, with each nest producing a single fledgling. As was reported above (see *Results & Discussion: Active*

Nest Dissuasion), a total of 43 Caspian terns eggs were detected on Goose Island during the 2015 nesting season, and all but three of these Caspian tern eggs either depredated by gulls or collected under permit. The majority of the Caspian tern eggs laid on Goose Island in 2015 were in open or sparsely vegetated habitat just above the island's shoreline where passive dissuasion materials were not installed. Some of the Caspian tern eggs that were laid in these shoreline areas were not in visible nest scrapes, and were apparently abandoned immediately after laying. Most of these Caspian tern eggs (n=23) were depredated by gulls within a day of being laid, and the remaining tern eggs (n=17) were collected under permit, within hours of being laid.

In 2015, gulls were first observed on Goose Island in late February and their numbers increased until a camp was installed on the island (19 March) which allowed researchers to spend the night on the island and initiate regular active hazing during dawn and dusk periods (*Figure 4*). This had an effect in reducing the number of gulls on the island until they became habituated to the active hazing beginning in early April and lasting through the remainder of the breeding season (*Figure 4*). The index of gull colony size on Goose Island in 2015 was ca. 14,800 individuals (ca. 9,600 ring-billed gulls and ca. 5,200 California gulls), a small increase in the number of individual gulls counted on Goose Island as compared to last year (ca. 14,300; BRNW 2014b). This compares with an index of about 11,500–13,000 gulls counted on the Goose Island during the three years prior to management (Adkins et al. 2014; BRNW 2014b). These index counts suggest an increase in overall gull colony size in recent years, and support the conclusion that the combined effects of active and passive nest dissuasion efforts in 2014 and 2015 had little impact on the establishment and size of the Goose Island gull colony during those years.

In summary, nest dissuasion efforts were largely successful in preventing Caspian terns from nesting on Goose Island and the surrounding islets in 2015. Despite their inability to form a colony, some Caspian terns showed strong site fidelity to Goose Island, perhaps bolstered by the presence of a large gull colony on the island that served to attract prospecting Caspian terns. Another likely factor in the strong site fidelity exhibited by some Caspian terns at Goose Island is an extended history of nesting on the island (potentially since 2004; Adkins et al. 2014). However, the Crescent Island Caspian tern colony has been present annually since 1986, suggesting that colony longevity is not the primary explanation for the strong site fidelity exhibited by some Goose Island Caspian terns. A third potential factor that might explain the strong site fidelity of some Caspian terns to Goose Island, compared to Crescent Island, is the paucity of alternative suitable Caspian tern nesting habitat in the area of Potholes Reservoir. In contrast, Caspian terns and gulls nesting on Crescent Island have access to numerous islands located on the mid-Columbia River that provided ample suitable nesting habitat for ground-nesting colonial waterbirds (e.g., the Blalock Islands for both Caspian terns and gulls, and Badger Island for gulls; *see below*). Finally, a fourth potential factor in the apparent stronger site fidelity of Caspian terns at Goose Island compared to Crescent Island is the type of passive nest dissuasion materials deployed at the two islands. The majority of potential Caspian tern nesting habitat on Crescent Island was covered with fence rows of privacy fabric erected at 15-foot intervals. This passive dissuasion technique has proven to be highly effective for Caspian terns nesting in the Columbia River estuary, and appears to have been equally effective on

Crescent Island. The shallow, rocky soils of Goose Island precluded the use of this passive nest dissuasion technique on that island.

Crescent Island

After a brief period when Caspian terns were allowed to land on Crescent Island for capture, satellite tagging, and banding (29 March – 2 April; see *Methods & Analysis: Inter-colony Movements*), the combination of passive and active nest dissuasion techniques were successful in preventing Caspian terns from landing, roosting, or nesting on Crescent Island. A total of 474 breeding pairs of Caspian terns nested on Crescent Island in 2014, and all were displaced in 2015 (*Figure 5*).

Efforts to dissuade Caspian terns from nesting on Crescent Island were also successful in preventing all gulls from nesting there in 2015. In 2014, we estimated that ca. 6,400 individual gulls (ca. 5,600 California gulls and ca. 800 ring-billed gulls) nested on Crescent Island, all of which were displaced in 2015.

In summary, nest dissuasion activities were successful in preventing all nesting by both Caspian terns and gulls on Crescent Island in 2015. This was somewhat unexpected because the colonies of Caspian terns and gulls have been present on Crescent Island since soon after the island was built in 1985 (Ackerman 1994), and 2015 was the first year that nest dissuasion activities were implemented at Crescent Island. Several other factors (*see above*) may explain the abandonment of Crescent Island by both nesting gulls and Caspian terns in the first year nest dissuasion activities were implemented.

Alternative Sites

Caspian terns were confirmed present at 26 different sites during aerial surveys conducted in the Columbia Plateau region during the 2015 nesting season (see *Map 6*; *Table 1*). The majority of sites (n=21) were loafing sites, with no signs of nesting activity, and most of those (n=16) were located on the mid-Columbia River (*Table 1*). At all but five sites where Caspian terns were observed on the ground during aerial surveys, Caspian terns were on substrates that were not suitable for nesting (e.g., exposed rocks, mud flats, or gravel bars subject to periodic inundation; *Table 1*); subsequent air, land, and boat-based surveys suggested that Caspian terns did not attempt to nest at any of these 21 sites.

During aerial surveys in 2015, Caspian terns were confirmed to be present at six of 12 prospective colony sites (see *Map 1*). The six prospective sites where Caspian terns were observed included three sites on the mid-Columbia River (Blalock islands complex, Badger Island, and Foundation Island) and three sites off the Columbia River (Twinning Island in Banks Lake, Harper Island in Sprague Lake, and the small unnamed island in Lenore Lake; see *Map 1*). The prospective sites where Caspian terns were not observed during aerial surveys in 2015 included five sites on the mid-Columbia River (Miller Rocks, Three Mile Canyon Island, Island 18, Island 20, and Cabin Island) and one site off the Columbia River (Solstice Island in Potholes Reservoir; see *Map 1*).

Nesting activity by Caspian terns was detectable during aerial surveys and in oblique aerial photography taken at five historical breeding sites in 2015: Goose Island (main island) in Potholes Reservoir, the Blalock Islands on the mid-Columbia River, Harper Island in Sprague Lake, Twinning Island in Banks Lake, and an unnamed Island in Lenore Lake (see *Map 1*). Subsequent land- and boat-based surveys confirmed that these five sites supported active Caspian tern breeding colonies in 2015.

Blalock Islands – The Blalock Islands are located on the Columbia River above John Day Dam near the town of Irrigon, OR, and are owned and managed by the U.S. Fish and Wildlife Service as part of Umatilla National Wildlife Refuge. The island group consists of several sizable, permanently vegetated islands, as well as numerous low-lying gravel islands and mudflats that were created by the John Day Dam impoundment.

The Blalock Islands have been the site of multiple breeding colonies of several species of piscivorous waterbird, including Caspian terns, Forster's terns, California gulls, ring-billed gulls, great blue herons, great egrets, and black-crowned night-herons. Nesting by Caspian terns on the Blalock Islands was first detected in 2005, when six pairs attempted to nest on Rock Island (BRNW 2015a, Adkins et al. 2014), a low-lying gravel and cobble island. The history of Caspian tern nesting in the Blalock Islands during 2005-2014 is characterized by small colonies (average = 56 breeding pairs; range = 6–136 breeding pairs) that moved frequently among islands (six different islands used for nesting during 2005-2014; see *Map 10*), and experienced poor nesting success. Nesting attempts by Caspian terns on the Blalock Islands typically failed or nearly failed to raise any young, either due to nest predation by mammalian or avian predators, or due to high water levels in John Day Pool during the incubation period and inundated nesting areas (BRNW 2015a).

In 2015, Caspian terns were first seen in the Blalock Islands on 25 March, when 10 roosting adults were observed on Sand Island. The first evidence of nesting by Caspian terns at the Blalock Islands during 2015 was observed on 19 April when 12 attended Caspian tern nests, including three with eggs, were counted on Middle Island (see *Map 10* and *Map 11*). In the weeks that followed Caspian tern nests were confirmed on Long Island (26 April) and Southern Island (30 April; see *Map* 10 and *Map* 11). As many as ca. 1,300 Caspian terns and 649 attended Caspian tern nests were counted during field visits to the Blalock Islands from 19 April to 15 August. Using vertical aerial photography collected on 20 May 2015, during the peak of breeding, a total of 677 pairs of Caspian terns were estimated to have attempted to nest on the three small Blalock Islands, more than a 10-fold increase in colony size as compared to the average colony size during 2005-2014 (*Figure 6*). We estimated that 247 young Caspian terns fledged from the Blalock Islands in 2015 or a productivity of 0.37 young raised per breeding pair, the highest Caspian tern nesting success ever observed at the Blalock Islands (BRNW 2015a). As in previous years, inundation of tern nests due to fluctuations in reservoir level was a factor limiting colony size and nesting success at the Blalock Islands in 2015.

Twinning Island – At the southern end of Banks Lake, near Coulee City, WA, two volcanic islands with thin topsoil provide nesting habitat for colonial waterbirds. These two sites, Goose Island and Twinning Island, are owned by the U.S. Bureau of Reclamation and managed in cooperation with the Washington Department of Fish and Wildlife.

From 1997 to 2005, Caspian terns nesting at Banks Lake used Goose Island, north of Twinning Island, where colony size ranged from 10 to 40 breeding pairs (Adkins et al. 2014). In 2005, Caspian terns began nesting on Twinning Island (also called Dry Falls Dam Island), which is located in Banks Lake just north of Dry Falls Dam. The colony at Twinning Island grew from less than 10 breeding pairs in 2005 to 67 breeding pairs in 2014 (BRNW 2015a). Also, there are large mixed species colonies of California and ring-billed gulls on both Goose and Twinning islands, with over 3,000 breeding individuals counted on each island in 2009 (BRNW 2015a). Recently, no young Caspian terns have been fledged from the colony at Twinning Island, likely due to human disturbance (the island is situated directly across from a popular boat launch), mammalian predators (the island is approximately 300 meters from the mainland), and competition and nest predation from gulls that also nest on the island (BRNW 2015a).

In 2015, Caspian terns were first seen on Twinning Island on 8 April, when one roosting tern was observed. The first evidence of nesting on Twinning Island was confirmed on 1 May when three attended Caspian tern nests were counted on the colony (see *Map 12*). As many as 131 Caspian terns and 64 attended Caspian tern nests were counted in subsequent visits to Twinning Island between 1 May and 2 July. Based on counts of oblique aerial photos, a total of 64 breeding pairs of Caspian terns attempted to nest on Twinning Island in 2015, similar to the estimated colony size in 2014 (67 breeding pairs; *Figure 7*; BRNW 2015a). In 2015, the first Caspian tern eggs were observed at the Twinning Island colony on 5 May; however, all Caspian tern nesting attempts at the island failed by 10 June (BRNW 2015a). The primary cause of Caspian tern colony failure in 2015 was thought to be a combination of avian and mammalian nest predation.

Harper Island – Harper Island is a privately-owned island located near the southwestern end of Sprague Lake between the towns of Ritzville and Sprague in east-central Washington. The island is located about 48 km from the nearest section of the Snake River. Harper Island is a steep-sided, rocky island approximately 10 acres in area and covered by upland shrub habitat, sparse herbaceous vegetation, and bare rock.

Nesting by Caspian terns on Harper Island in Sprague Lake was first documented in the late 1990s, and Caspian terns have nested sporadically there ever since (Adkins et al. 2014). During 2005-2011, estimates of Caspian tern colony size on Harper Island were generally very small (< 10 breeding pairs), before increasing about 6-fold in 2012, and then declining again to just 8 breeding pair in 2014 (BRNW 2015a). The island has also been home to a large California and ring-billed gull colony and a double-crested cormorant colony (BRNW 2015a). As was the case at Twinning Island in Banks Lake, no young Caspian terns were apparently fledged from the Harper Island colony during 2012-2014; the cause[s] of colony failure is not known (BRNW 2015a).

In 2015, Caspian terns were first seen on Harper Island on 16 May, when three attended nests were confirmed to be active (see *Map 13*). As many as 17 Caspian terns and 10 attended Caspian tern nests were counted during visits to Harper Island from 16 May to 8 July. A total of 10 breeding pairs of Caspian terns apparently attempted to nest on Harper Island in 2015, similar to the estimated colony size in 2014 (8 breeding pairs; *Figure 8*; BRNW 2015a). In 2015, egg-laying was not confirmed at the Harper Island Caspian tern colony prior to colony abandonment, which was confirmed on 5 July; the cause[s] of colony failure in 2015, as well as colony failure the previous year (BRNW 2015a), is not known.

Lenore Lake – In 2014, an incipient Caspian tern breeding colony was discovered on a small unnamed island on Lenore Lake (just north of Soap Lake, WA), where two breeding pairs of Caspian terns were detected among nesting gulls. This Caspian tern colony was active again in 2015, growing to 16 breeding pairs (see *Map 14*). Caspian terns were first observed breeding at Lenore Lake on 18 June, shortly after the Caspian tern colony at Twinning Island (located 23 km away) failed. In addition to Caspian terns, double-crested cormorants and ring-billed gulls also nested on this small island. Six young Caspian terns were fledged from the colony in 2015, while no Caspian terns fledged from the colony the previous year.

Region-wide Nesting Population

In total, an estimated 769 breeding pairs of Caspian terns nested at five different breeding colonies in the Columbia Plateau region during 2015 (*Figure 9*). All but one of the Caspian tern colonies that were active in the region during 2014 were active again in 2015; the lone exception was the Crescent Island colony, where nest dissuasion efforts were successful in preventing any Caspian terns from nesting in 2015 (*Figure 10*). The estimated total population of Caspian terns nesting in the Columbia Plateau region in 2015 (769 breeding pairs) was similar to the estimated population nesting in the region in 2014 (755 breeding pairs), but still lower than the average population observed during 2000-2013 (*Figure 9*; BRNW 2015a). These results suggest that although the nest dissuasion actions implemented on Goose and Crescent islands in 2015 were effective in eliminating (Crescent Island) or greatly reducing (Goose Island) the numbers of Caspian terns nesting at those sites, they did not result in a significant reduction in the total number of Caspian terns breeding in the region compared to 2014. The reason for this result was the more than 10-fold increase in the number of Caspian terns nesting at the Blalock Islands in 2015 (677 breeding pairs) relative to the average colony size during 2005-2014 (56 breeding pairs; *Figure 10*). This was the largest Caspian tern breeding colony ever recorded at the Blalock Islands (*Figure 6*) and similar in size to the largest Caspian tern colony anywhere in the Columbia Plateau region since intensive monitoring began in 2000 (BRNW 2015a).

INTER-COLONY MOVEMENTS

A total of 222 previously color-banded Caspian terns were resighted in or near Potholes Reservoir, including on Goose Island, in 2015 (*Table 6*). The islands in North Potholes Reservoir and the marsh unit in the Columbia National Wildlife Refuge are both within 10 km of Goose Island, and 10 of the 222 color-banded Caspian terns were resighted at one of those locations.

Of the 222 Caspian terns that were resighted in or near Potholes Reservoir in 2015, 86% were previously banded at Goose Island, 7% were banded at Crescent Island, 2% were banded at Sheepy Lake in Lower Klamath National Wildlife Refuge California, 2% were banded at East Sand Island, and 1% were banded each at the Port of Bellingham (Puget Sound coast of Washington), at Brooks Island (San Francisco Bay), and at Crump Lake (Warner Valley, interior Oregon), and < 1% was banded at Malheur Lake in Malheur National Wildlife Refuge, Oregon. (see *Map 15*).

A total of 515 previously color-banded Caspian terns were resighted at the active Caspian tern breeding colony and loafing sites in the Blalock Islands during 2015 (see *Map 15*; *Table 7*). Of these, 60% were previously banded at Crescent Island, 35% were banded at Goose Island-Potholes Reservoir, 2% were banded at East Sand Island, and 1% were banded each at the Port of Bellingham, Sheepy Lake, and Malheur Lake, and < 1% was banded at Crump Lake, Oregon (see *Map 15*).

A total of 52 previously color-banded Caspian terns were resighted at a small colony on Twinning Island in Banks Lake. Of these, 81% were banded at Goose Island and 19% were banded at Crescent Island. A total of 8 previously color-banded Caspian terns were resighted at a small colony on Lenore Lake. Of these, 75% were banded at Goose Island and 25% were banded at Crescent Island (see *Map 15*).

In McNary Pool in the Columbia River, a total of five previously color-banded Caspian terns were resighted at non-breeding sites. One Caspian tern that was previously banded at Crescent Island was resighted at Borgans Island, two Caspian terns (one banded at Crescent Island and the other at East Sand Island) were resighted at the mouth of Snake River, and two Caspian terns (one banded at Crescent Island and the other at East Sand Island) were resighted at Finley Island (see *Map 15*). At Priest Rapids Reservoir, four Caspian terns previously color-banded at Goose Island were resighted loafing near Desert Aire. Five previously color-banded Caspian terns were resighted loafing at Cabin Island, also in Priest Rapids Reservoir (see *Map 15*); however, positive identification of those banded individuals was not possible.

Of a total of 451 color-banded Caspian terns seen on Crescent Island in 2014, 262 terns were resighted again elsewhere in 2015; some of these individuals were resighted at multiple locations in 2015. Of a total of 336 resighting records of these birds in 2015, 71% were resighted on the Blalock Islands, 9% were resighted in the Potholes Reservoir area, 8% were resighted at East Sand Island, 4% were resighted at Malheur Lake, 3% were resighted at Twinning Island, 2% were resighted at Tule Lake National Wildlife Refuge, and 1% were resighted each in McNary Pool, Lenore Lake, East Link Impoundment at Summer Lake Wildlife Area, and at an active colony on Rat Island in the Puget Sound area, Washington during 2015 (see *Map 15*; *Table 8*).

Of a total of 291 color-banded Caspian terns seen on Goose Island in 2014, 224 were resighted again in 2015, either at Goose Island or elsewhere; some of which were resighted at multiple locations in 2015. Of a total of 371 resighting records of these birds in 2015, 39% were resighted in the Potholes Reservoir area, 33% were resighted at the Blalock Islands, 10% were resighted at Twinning Island, 5% were resighted at Malheur Lake, 4% were resighted each at East Sand Island and Tule Lake NWR, 2% were resighted at Rat Island (Washington), 1% were resighted each at Lenore Lake, an active tern colony in Everett (coastal Washington), and Priest Rapids Reservoir, and < 1% were resighted each at an active colony on Rice Island in the Columbia River estuary and at Sheepy Lake (California) during 2015 (see *Map 15*; *Table 9*).

In summary, these results suggest that Caspian terns exhibited strong site fidelity to the Potholes Reservoir area despite the second year of efforts to dissuade Caspian terns from nesting at Goose Island. Furthermore, band resightings in 2015 revealed where Caspian terns dissuaded from colonies on Goose and Crescent islands were recruited. The Blalock Islands experienced a large influx of nesting Caspian terns in 2015, from both colonies on Crescent Island and Goose Island, but predominantly from Crescent Island. A much smaller influx of Caspian terns from Goose and Crescent islands was observed at other colonies in the Columbia Plateau region. Although the majority of Caspian terns dissuaded from Goose and Crescent islands remained in the Columbia Plateau region, some Caspian terns also dispersed to breeding or non-breeding sites along the coasts of Washington and Oregon, as well as to colonies in interior Oregon and northeastern California. These results offer some insight into potential locations where Caspian terns from the Columbia Plateau region would recruit back into the breeding population, if further management of Caspian terns in the Columbia Plateau region occurs in the future.

Out of 11 *a priori* models constructed in 2015, a model with transition (from one region to another) and year effects on inter-regional movement probabilities was selected based on the smallest value of AICc. This model included an interaction term between transition and year effects, which allows movement probabilities to vary over years regardless of trends observed in other transitions. Movement probabilities of Caspian terns banded as adults from the Columbia Plateau region to the Columbia River estuary ranged from < 0.01% to 4.4% per year during 2006-2015, with the highest in 2015. This translates into an estimated movement of a total of 67 Caspian terns form the Columbia Plateau to the Columbia River estuary (*Table 10*). Movement probability in the opposite direction was lower (1.4%) in 2015; however, because of the large size of the source colony at East Sand Island, estimated net movement of adult Caspian terns (the estimated number of terns that moved from one region to another, subtracted from the number of terns that moved in the opposite direction) from the Columbia River estuary to the Columbia Plateau in 2015 was 105 individuals. Although the number was small, this could partially off-set benefits to salmonids of tern management in the estuary because per bird impacts on smolt survival are higher for terns nesting in the Columbia Plateau region compared to those nesting in the estuary, where marine forage fishes (anchovy, smelt, surfperch, etc.) tend to dominate the diet.

Based on the best model selected to estimate inter-regional movements (see above), movement probabilities of Caspian terns banded as adults from the Columbia Plateau region to the alternative colony sites on the Corps-constructed tern islands in interior Oregon and northeastern California ranged from < 0.01% to 10% per year during 2008-2015, with the highest in 2012 and 0.7% in 2015. This translates into an estimated movement of a total of 11 Caspian terns from the Columbia Plateau to the Corps-constructed islands in 2015 (*Table 10*). Movement probabilities from colonies on the Corps-constructed islands to the Columbia Plateau region ranged from < 0.01% to 20% during 2009-2014, with the highest in 2014. The movement probability from the alternative colony sites to the Columbia Plateau remained high at 19% in 2015 despite management actions at Crescent Island and Goose Island. Estimated net movement of adult Caspian terns from the Corps-constructed alternative colony sites to the Columbia Plateau in 2015 was 282 individuals. The drought in 2014 and 2015 not only made some of the Corps-constructed islands more accessible to terrestrial predators (e.g. raccoons), but also limited foraging habitat and prey availability within commuting range of Caspian terns nesting on Corps-constructed islands. The sustained high movement probability from the alternative colony sites to the Columbia Plateau region in 2015 might have been partly due to available nesting habitat at Blalock Islands in the mid-Columbia River and terns' strong fidelity to Goose Island in the Potholes Reservoir.

SMOLT PREDATION RATES

Table 11 provides data on colony sizes, predation rates, and average per capita predation rates for Caspian terns nesting at Goose Island, Crescent Island, and the Blalock Islands during 2007-2014. Data indicate that predation rates were variable depending on the Caspian tern colony, the year, and the ESU/DPS of salmonid. In general, predation rates and per capita predation rates were higher on steelhead DPSs compared with salmon ESUs, particularly predation on Upper Columbia River steelhead by Caspian terns nesting on Goose Island and predation on Snake River steelhead by Caspian terns nesting on Crescent Island (*Table 11*). Colony size also varied by location and year. In the case of Goose Island, variation in colony size was due in part to management actions in 2014 that reduced the colony to 159 breeding pairs from a pre-management annual colony size of 282-487 pairs *(Table 11*).

In 2015, Caspian tern colony size at Goose Island was estimated to be between 14 and 39 breeding pairs (although only 2 breeding pairs persisted throughout the nesting season; see *Methods & Analysis: Smolt Predation Rates*); there were 0 breeding pairs at Crescent Island; and 677 breeding pairs nested at the Blalock Islands (*Table 11*). For the second consecutive year, as part of implementation of the IAPMP, the number of Caspian terns nesting on Goose Island was reduced substantially relative to pre-management counts during 2007-2013 (*Table 11*). The Caspian tern colony at Crescent Island was completely precluded in 2015, the first year of nest dissuasion efforts at that site, a reduction of 349-474 pairs compared to colony size during 2007-2014 (*Table 11*). Counts of breeding pairs of Caspian terns at the Blalock Islands in 2015 (677 pairs) were the highest ever recorded at that site (range = 6-136 pairs during 2007-2014; *Table 11*).

Based on estimates of Caspian tern colony size in 2015 and per capita predation rates during 2007-2014 (*Table 12*), we predict that the predation rates on ESA-listed salmonid populations by Goose Island Caspian terns were substantially reduced in 2015 compared to both 2014 (post-management) and during 2007-2013 (pre-management; *Table 12*). This was especially true for Upper Columbia River steelhead, with a predicted predation rate in 2015 ranging from 0.5% (95% CI = 0.5-0.6%) for a colony size of 14 pairs to 1.5% (95% CI = 1.3-1.8%) for a colony size of 39 pairs (*Table 12*). In comparison, the average pre-management predation rate on Upper Columbia River steelhead was 15.7% (95% CI = 14.1-18.9%) during 2007-2013 (BRNW 2014b). For both colony size scenarios (14 pairs vs. 39 pairs), predicted Caspian tern predation rates on Upper Columbia River steelhead were below the IAPMP target goal of < 2%. Predicted predation rates on Upper Columbia River spring Chinook salmon (<0.2% for both colony size scenarios) and ESA-listed salmonid populations from the Snake River (< 0.1% for all ESUs/DPSs) were also well below the 2% threshold (*Table 12*).

Predicted predation rates by Crescent Island Caspian terns were <0.1% for all ESUs/DPSs of ESA-listed Columbia Basin salmonids in 2015 because there was no colony during the smolt out-migration period (*Table 12*).

Predicted predation rates on salmonid ESUs/DPSs by Caspian terns nesting in the Blalock Islands during 2015 were the highest of those evaluated herein due the colony's large size in 2015 (677 breeding pairs). Predicted predation rates were well above the 2% threshold for Upper Columbia River steelhead (6.2%; 95% CI = 4.8-8.5) and Snake River steelhead (4.8%; 95% CI = 3.8-6.0; *Table 12*). Predicted predation rates were also above the 2% threshold for Snake River sockeye salmon (2.7%; 95% CI = 0.6-7.6), but below the threshold for Upper Columbia River spring Chinook salmon, Snake River spring/summer Chinook salmon, and Snake River fall Chinook salmon (*Table 12*). It should be noted, however, that the Caspian tern colony in the Blalock Islands was much larger in 2015 than during 2007-2014 and, consequently, far outside the support of the model. The reliability of such extrapolation is therefore questionable.

In summary, a technique to calculate average per capita predation rates with a measure of uncertainty (95% Credibility Intervals) for various colony sizes and locations was used to predict predation rates by Caspian terns nesting on Goose Island, Crescent Island, and the Blalock Islands in 2015. As previously documented by BRNW (2015), Lyons et al. (2011a, 2011b) and Evans et al. (2012), per capita predation rates vary significantly by year, by colony, and by salmonid ESU/DPS, indicating that the benefits of Caspian tern management will also likely vary with these covariates.

Predicted predation rates indicate that the IAPMP target goal of achieving predation rates less than 2% on a given ESA-listed salmonid ESU/DPS, per Caspian tern colony, per year were met at both the Crescent Island and Goose Island Caspian tern colonies in 2015. Reduction in the size of the Caspian tern colony on Goose Island in 2015 (estimated at effectively 14-39 breeding pairs) suggests that predation rates on Upper Columbia River steelhead were substantially reduced compared with pre-management predation rates during 2007-2013 (mean = 15.7%; BRNW 2015a) and compared with post-management predation rates in 2014 (ca. 2.9%). Similarly, a lack of Caspian tern nesting on Crescent Island resulted in predicted predation rates of <0.1% for all ESUs/DPSs in 2015. Presumably this marks the first time since the colony was formed in the 1986 that no or very few salmonid smolts were consumed by Caspian terns nesting on Crescent Island.

Predicted predation rates on ESA-listed salmonid populations by Caspian terns nesting on the Blalock Islands were significantly higher than those observed during 2007-2014. Increases in predicated predation rates were commensurate with the increase in the size of the tern colony in 2015, with the colony increasing from an average of 59 breeding pairs during 2007-2014 to 677 breeding pairs in 2015. Predicted predation rate estimates suggest that predation by Caspian terns nesting on the Blalock Islands in 2015 were comparable to or higher than those of Caspian terns nesting on Crescent Island or Goose Island during 2007-2014 for most, but not all, of the ESUs/DSPs evaluated. Consequently, the increased predation rates on salmonid smolts by Caspian terns nesting on the Blalock Islands likely offset some of the benefits achieved by the reduction in the number of Caspian terns nesting on Crescent and Goose islands in 2015. The one exception appears to be consumption of Upper Columbia River steelhead, where cumulative predicted predation rates by all three Caspian tern colonies (Goose Island, Crescent Island, and the Blalock Islands) in 2015 were lower than those observed during 2007-2014, indicating an overall net benefit to Upper Columbia River steelhead due to Caspian tern management in the Columbia Plateau region during 2015.

Due to high inter-annual variation in predation rates and the documented influence of biotic factors (e.g., fish abundance, run-timing, fish condition) and abiotic factors (e.g., river flow, turbidity) on predation probabilities (Hostetter et al. 2012), predicted predation rates presented here may not be indicative of empirically-derived predation rates (those based on PIT tag recoveries) in any given year. Predicted predation rates are more likely to accurately reflect actual predation rates when Caspian tern colony sizes, river conditions, and prey abundances are similar to those observed during 2007-2014. In 2015, however, the Blalock Islands Caspian tern colony was significantly larger than during 2007-2014, and well outside of the bounds of the empirical PIT tag data collected at this site to estimate average per capita predation rates. Finally, a precise estimate of the predation rates on salmonid smolts by Caspian terns nesting at Goose Island was not available in 2015 because colony size was influenced strongly by both passive and active dissuasion activities. In lieu of a traditional colony size estimate at Goose Island, the number of nesting attempts (n=39) and the average number of adult terns counted on the island (n=28) during the nesting season were used instead.

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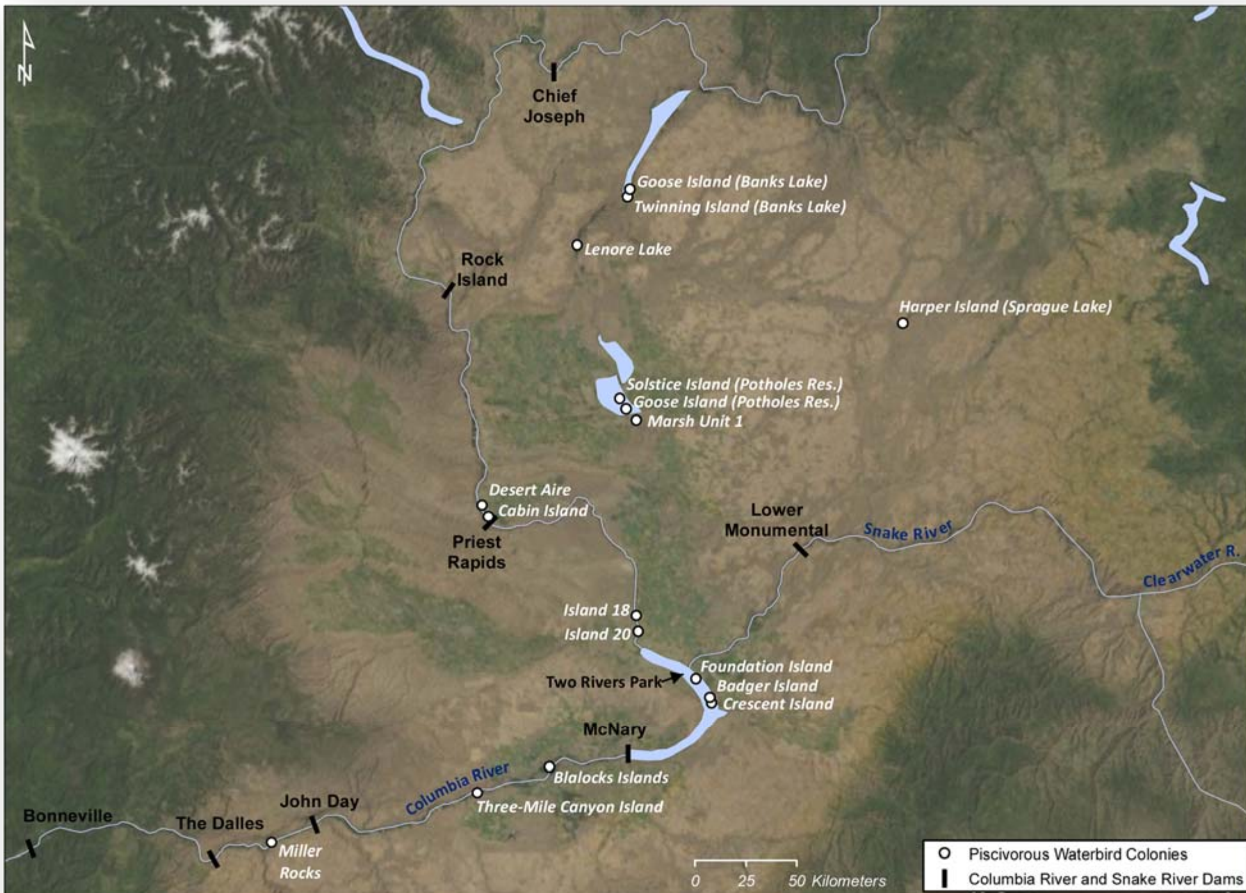
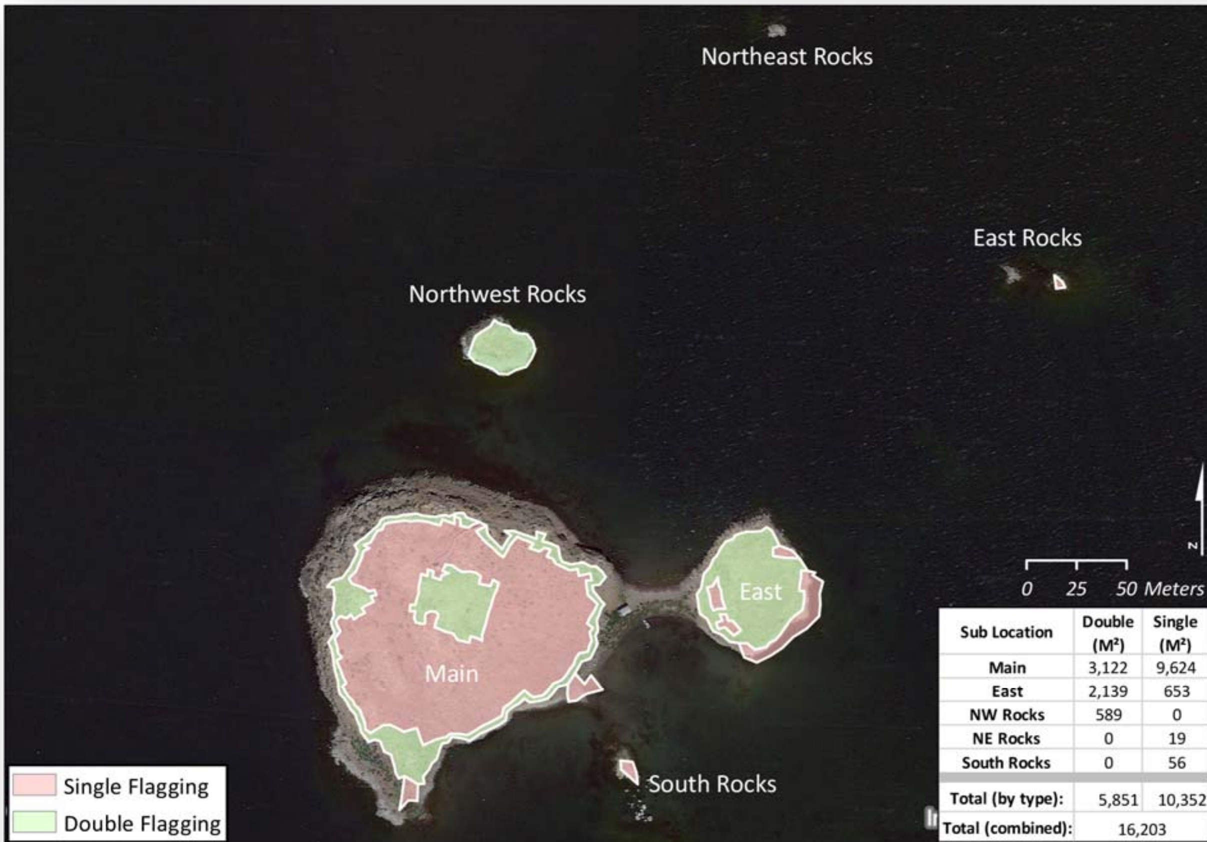
MAPS

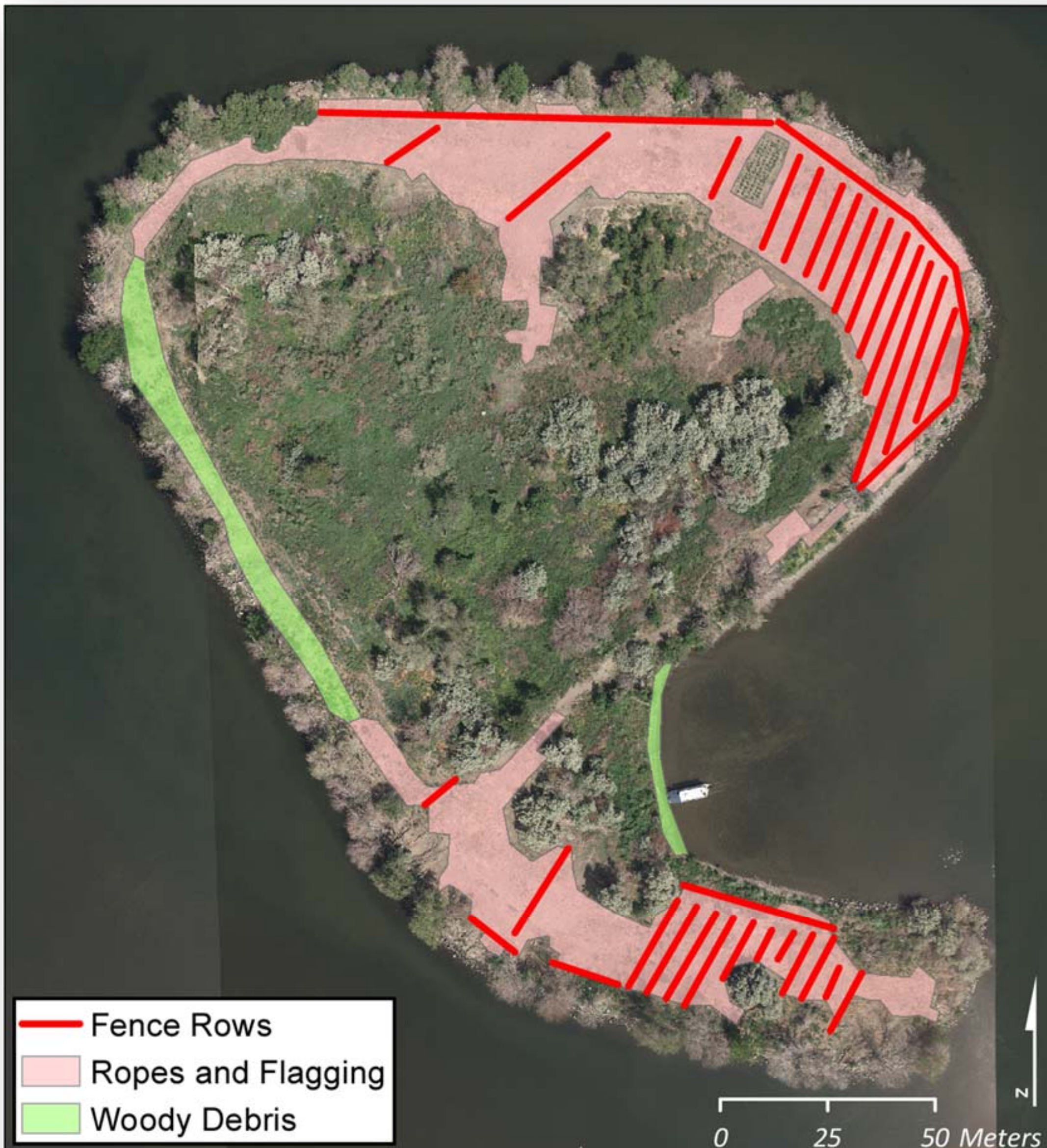


Map 1. Study area in the Columbia Plateau region in 2015.

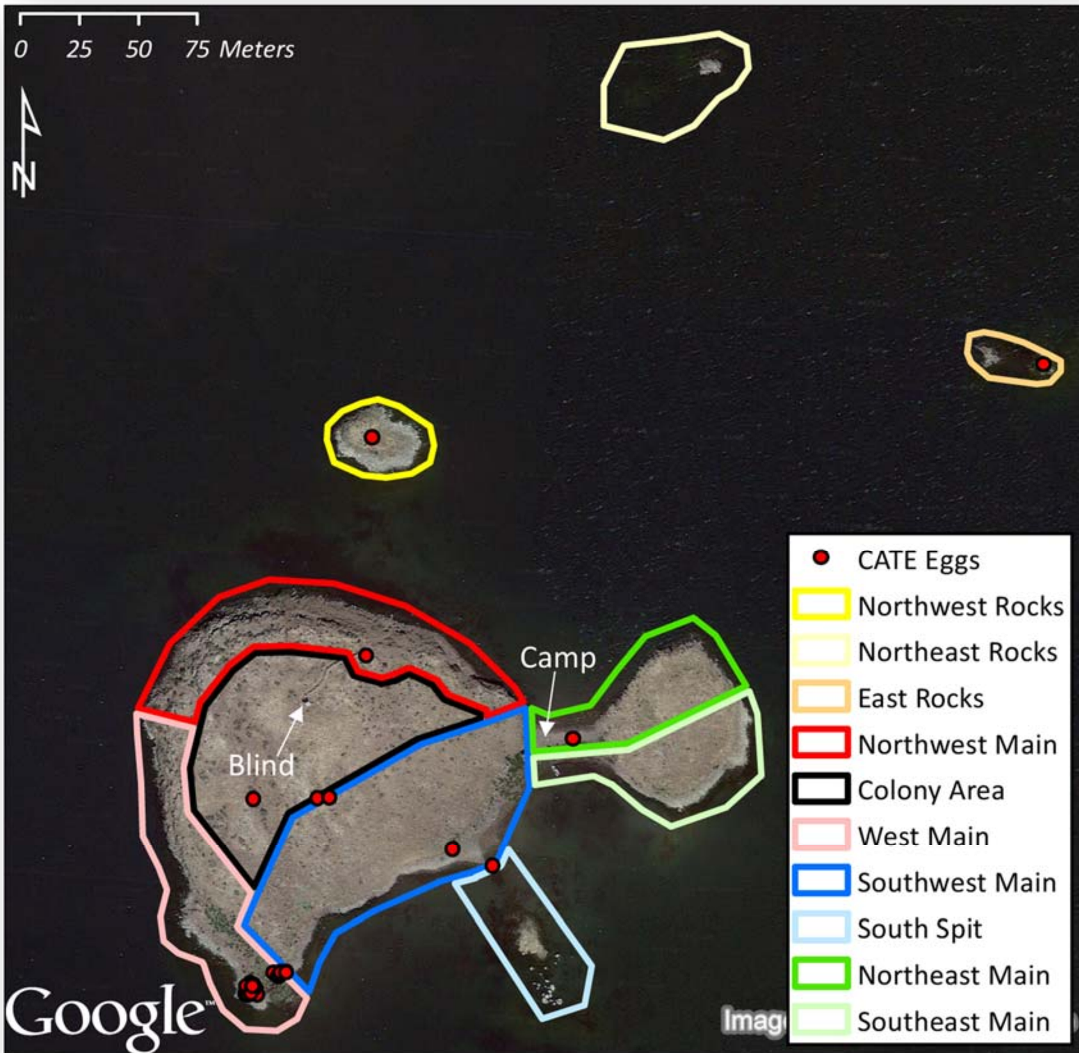


Sub Location	Double (M^2)	Single (M^2)
Main	3,122	9,624
East	2,139	653
NW Rocks	589	0
NE Rocks	0	19
South Rocks	0	56
Total (by type):	5,851	10,352
Total (combined):	16,203	

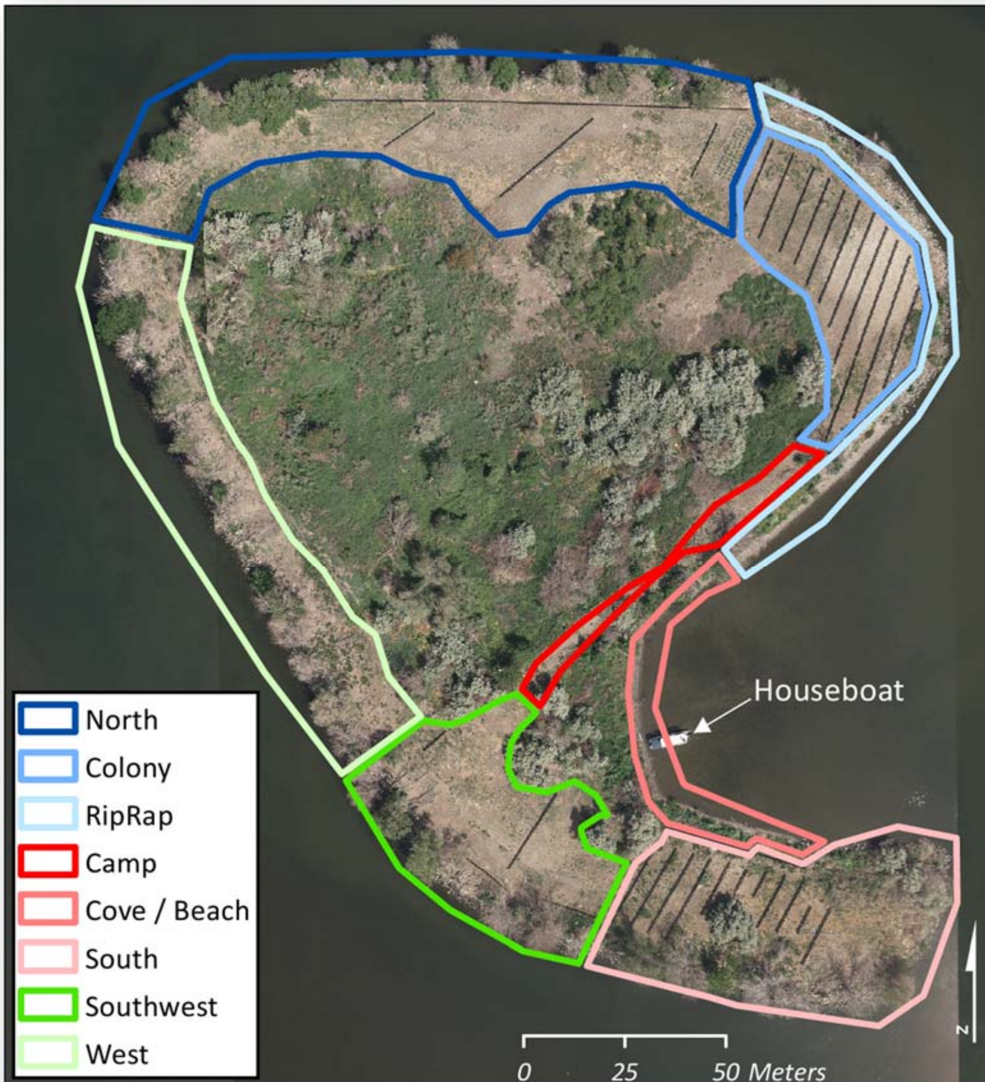
Map 2. Distribution of passive nest dissuasion materials on Goose Island and nearby rocky islets, Potholes Reservoir in 2015.



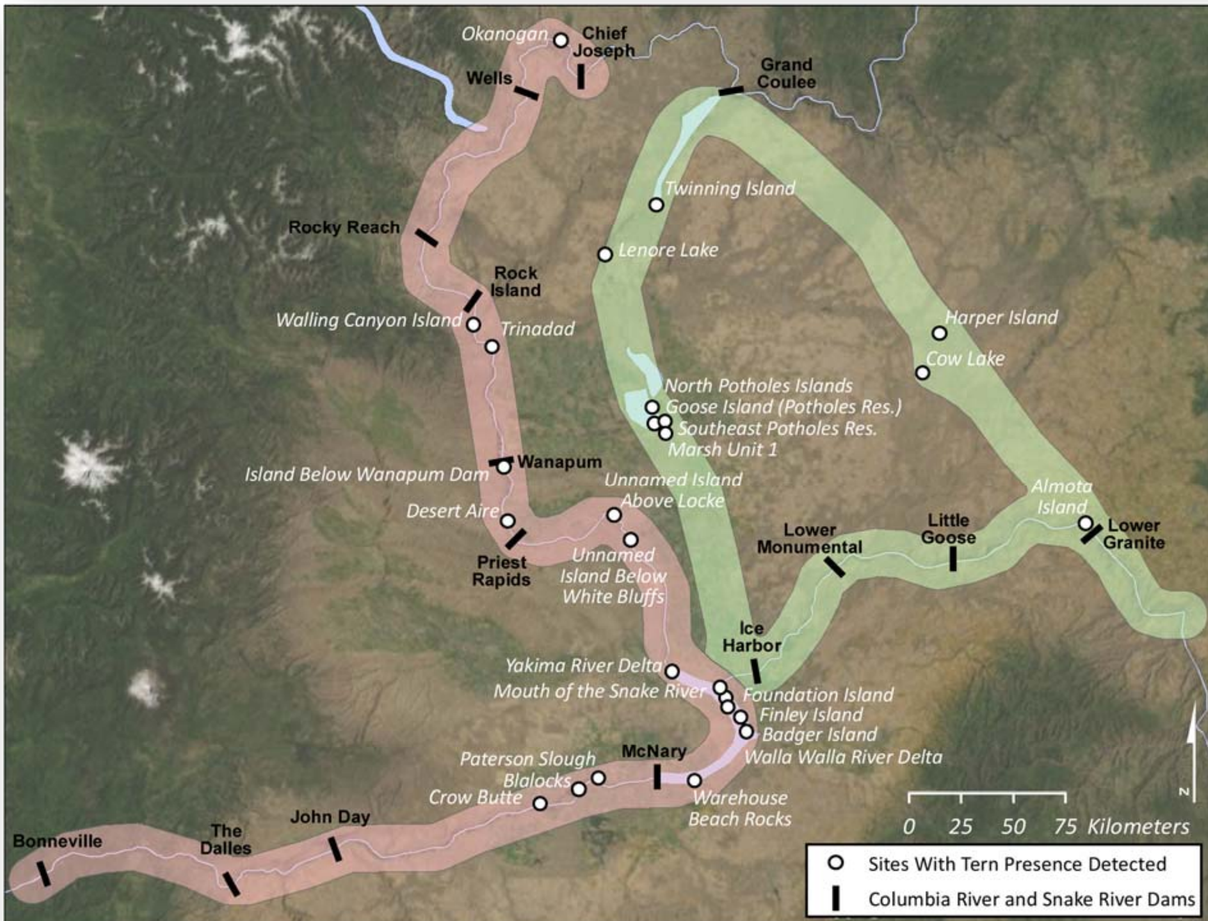
Map 3. Distribution of passive nest dissuasion materials on Crescent Island, mid-Columbia River in 2015.



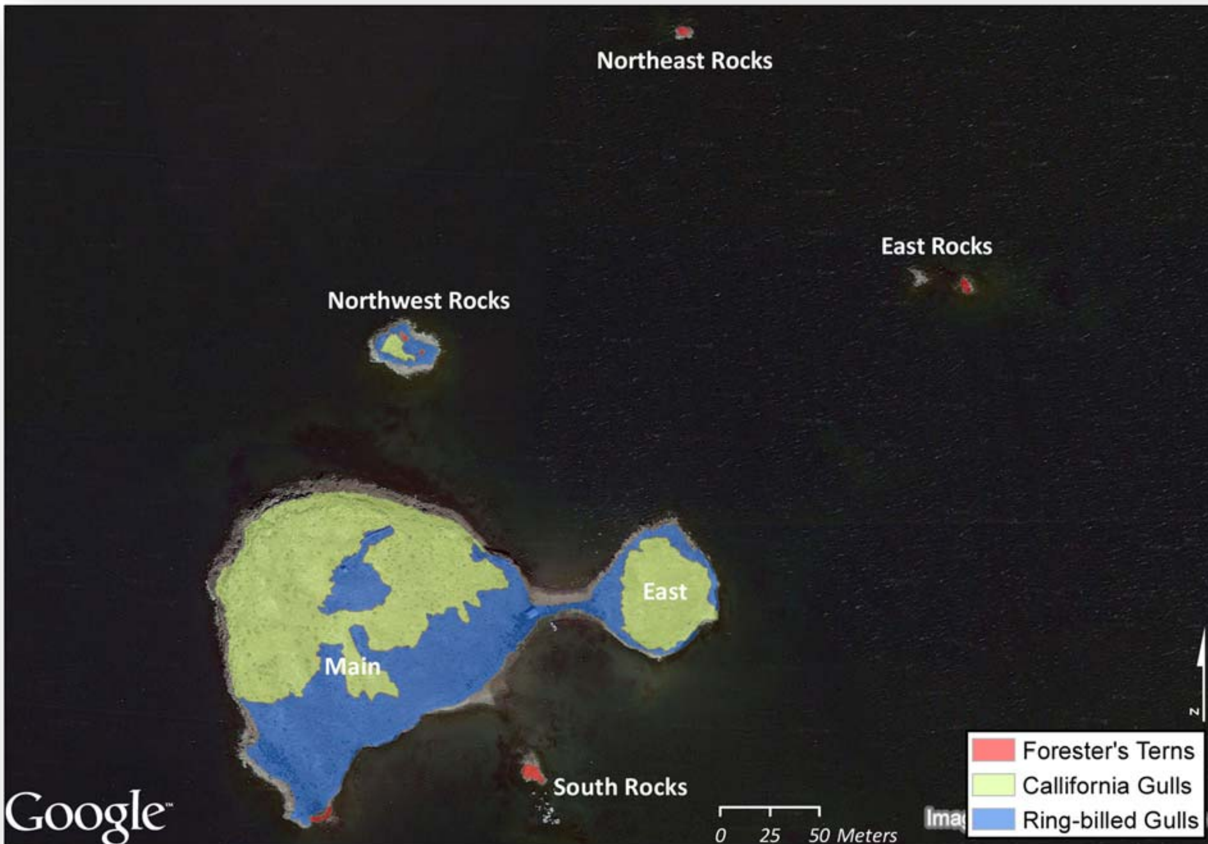
Map 4. Active dissuasion and survey locations on Goose Island and nearby rocky islets, Potholes Reservoir in 2015.



Map 5. Active dissuasion and survey locations on Crescent Island, mid-Columbia River in 2015.

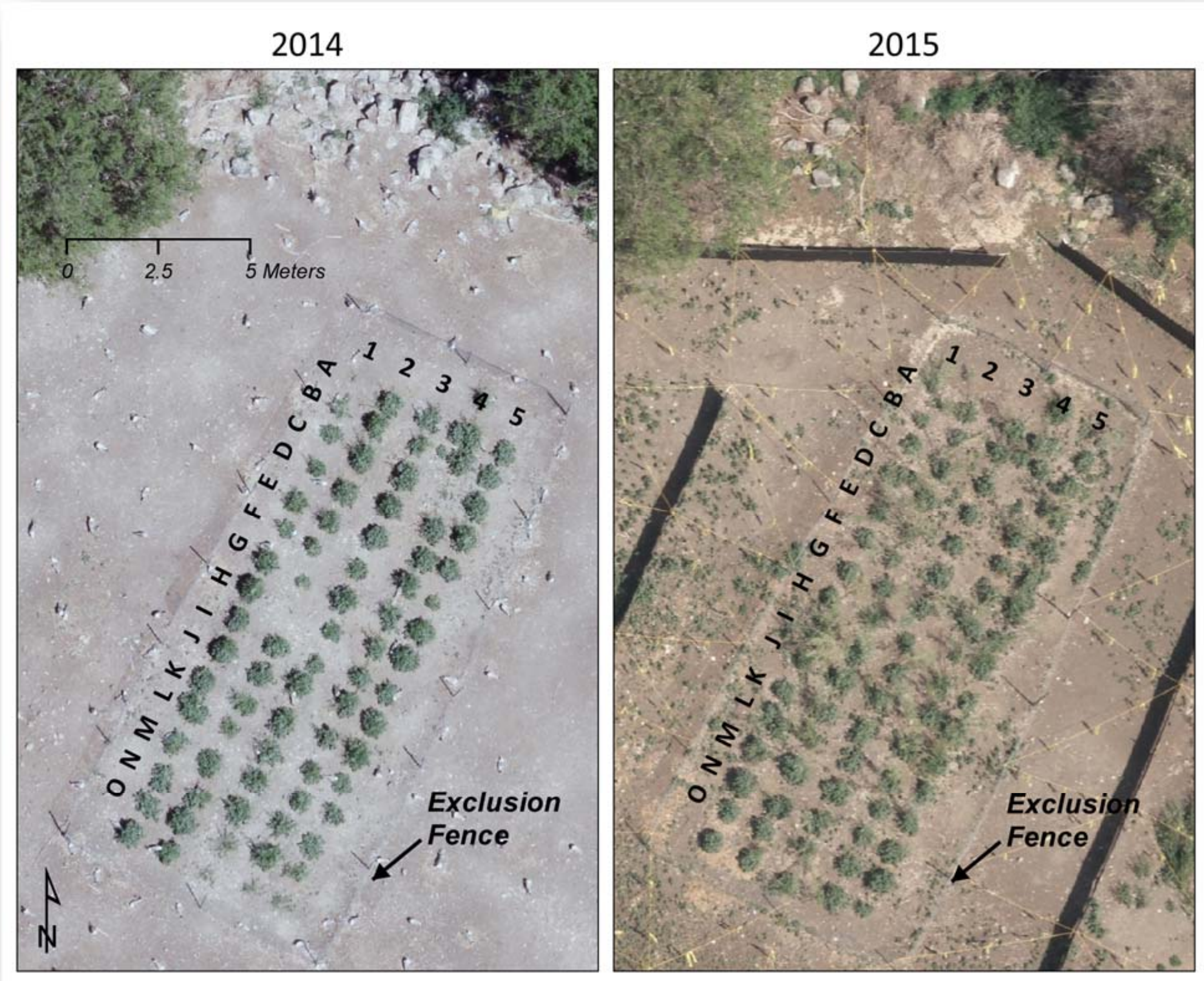


Map 6. Aerial survey flight paths along the Columbia and Snake rivers and at off-river locations within the Columbia Plateau region, including sites where Caspian terns were observed loafing and nesting in 2015.



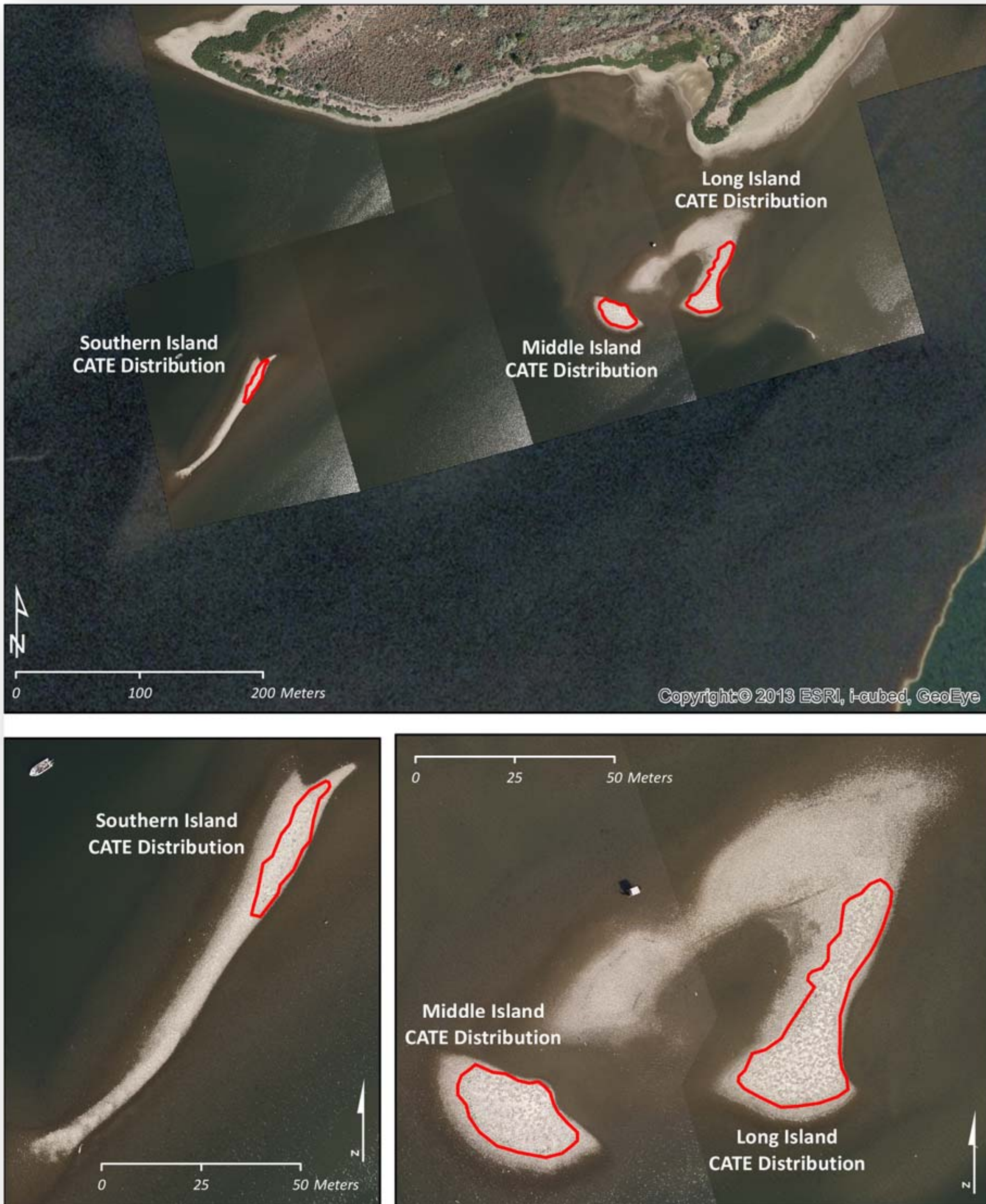
Map 7. Distribution of nesting California gulls, ring-billed gulls, and Forster's terns on Goose Island and the surrounding islets, Potholes Reservoir in 2015.

Map 8. Aerial imagery from June 2014 (top) and June 2015 (bottom) demonstrating the increase in vegetation at Crescent Island.



Map 9. Aerial image of the willow test plot on Crescent Island, mid-Columbia River in May 2014 and May 2015. Vegetation growth inside the plot includes planted native willows as well as non-native annuals. Holes for 75 individual plantings were drilled 3-4 feet apart in five columns (numbered 1-5 from east to west) and 15 rows (lettered A-O, running downslope from the island's edge). An exclusion fence was installed around the plot to protect the willows from browsing mammals.

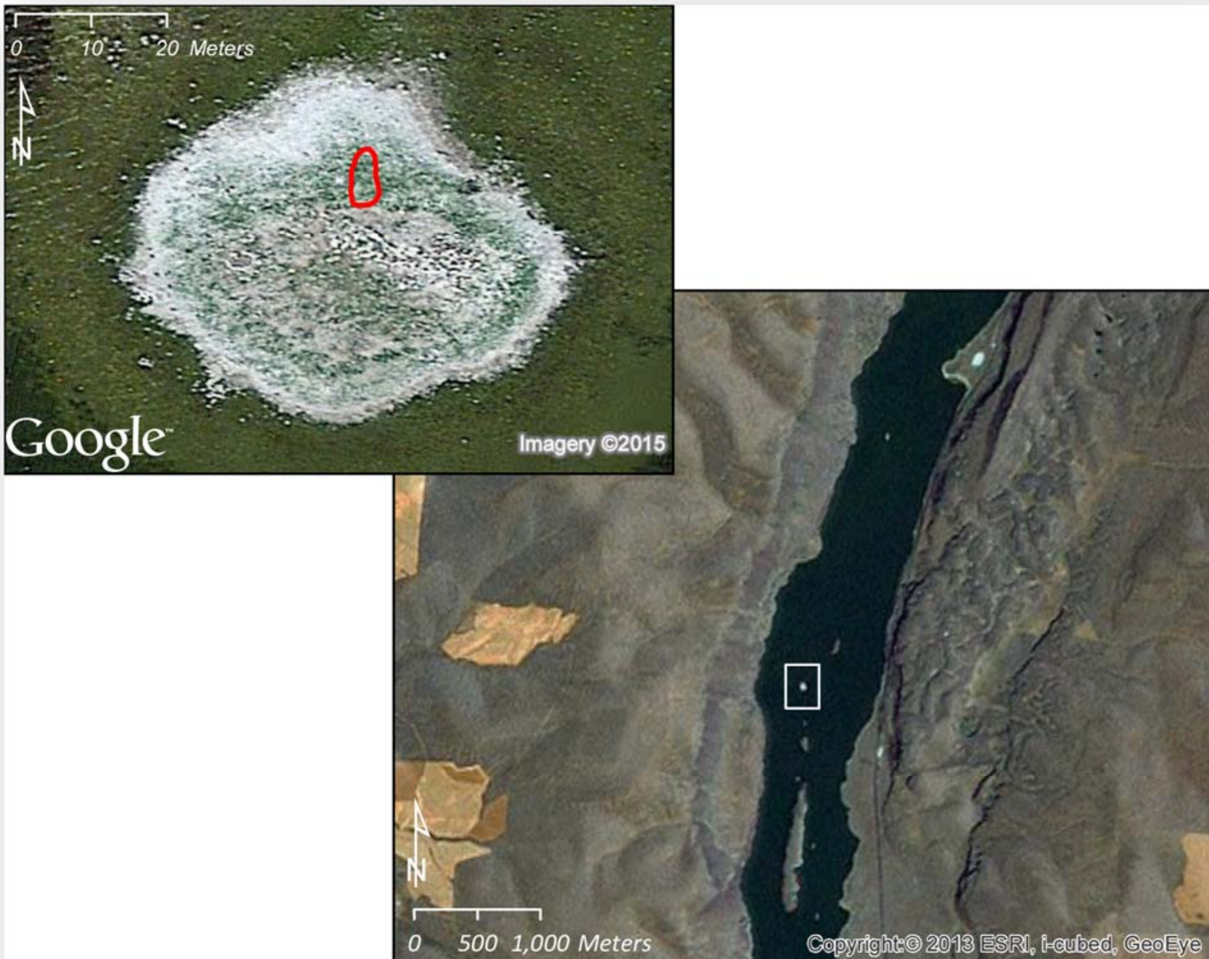
Map 10. Six islands within the Blalock islands complex, mid-Columbia River where piscivorous waterbirds have historically nested, including Southern, Middle, and Long islands where terns nested in 2015.



Map 11. Distribution of nesting Caspian terns on Southern, Middle, and Long islands within the Blalock islands complex, mid-Columbia River in 2015.

Map 12. Distribution of nesting Caspian terns on Twinning Island, Banks Lake in 2015.

Map 13. Distribution of nesting Caspian terns on Harper Island, Sprague Lake in 2015.



Map 14. Distribution of nesting Caspian terns on the small unnamed island, Lenore Lake in 2015.

Map 15. Locations where color-banded Caspian terns were resighted in 2015.

FIGURES

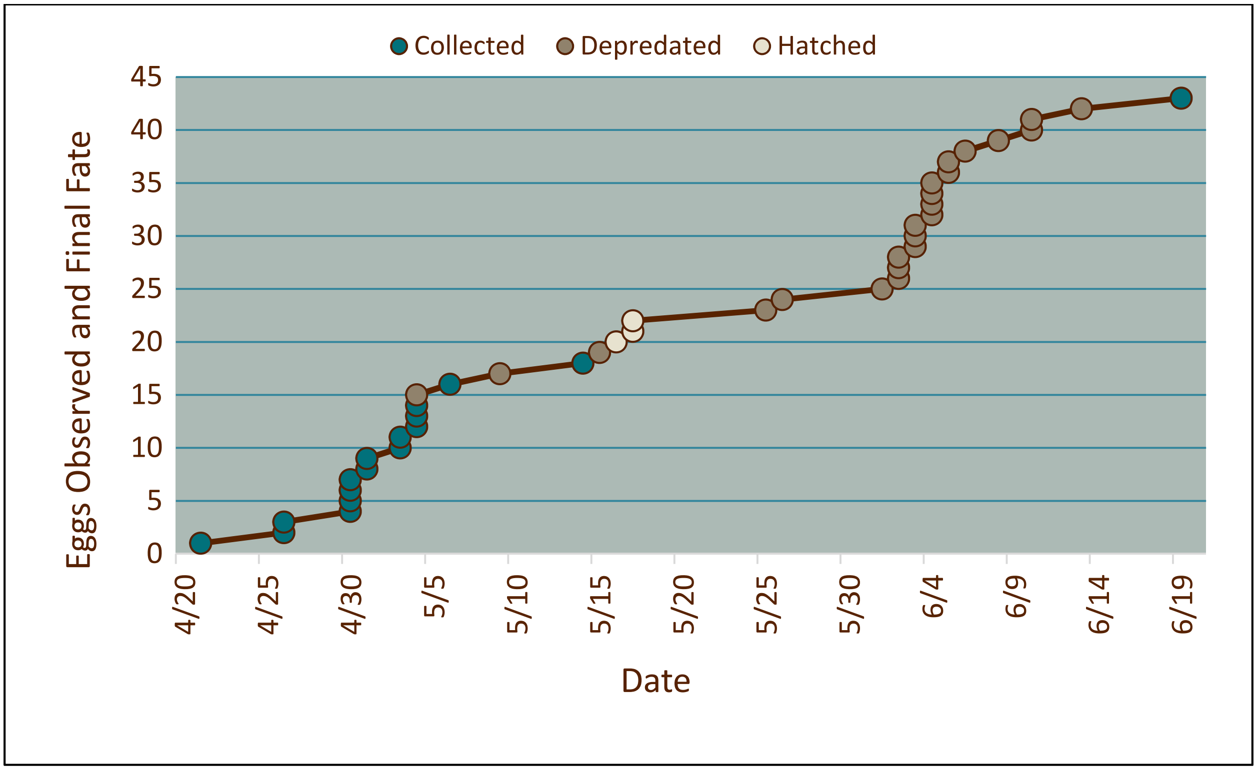


Figure 1. Caspian tern eggs observed on the Goose Island colony in 2015 and their final fate; collected under permit, depredated by gulls, or hatched.

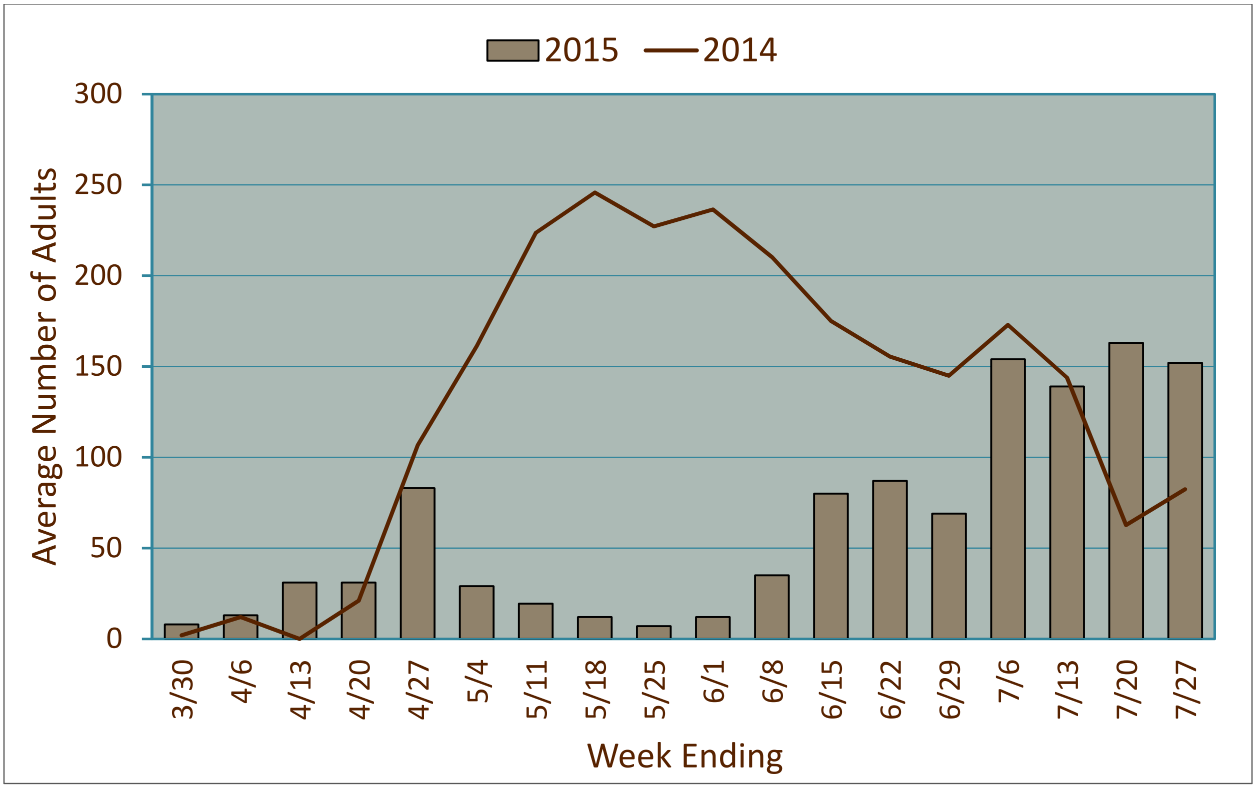


Figure 2. Weekly estimates from the ground of the numbers of adult Caspian terns on Goose Island and the surrounding islets (Potholes Reservoir) during the 2014 and 2015 breeding seasons.

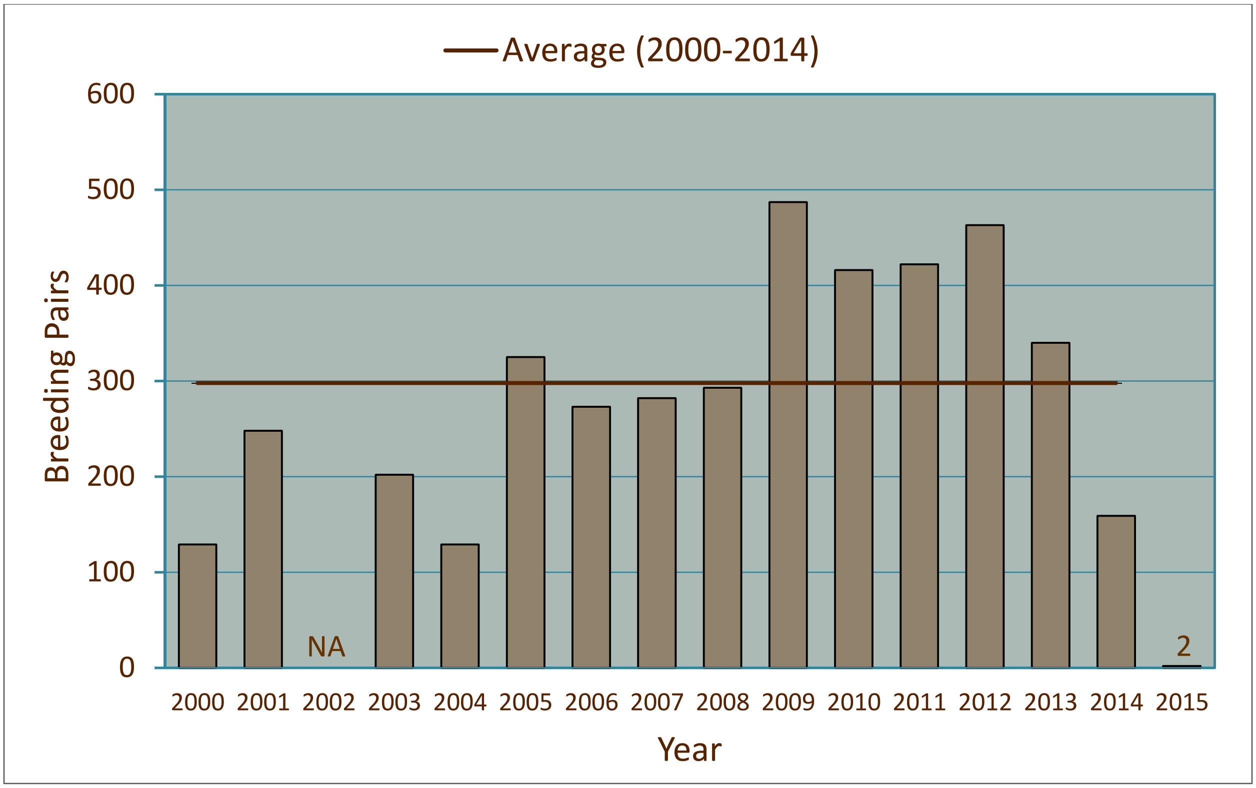


Figure 3. Size of the Caspian tern breeding colonies (number of breeding pairs) at Potholes Reservoir during 2000-2015. Colonies were located on Solstice Island during 2000-2004, Goose Island during 2004-2013, and mostly on Northwest Rocks just north of Goose Island in 2014. Colony size in 2002 was not determined.

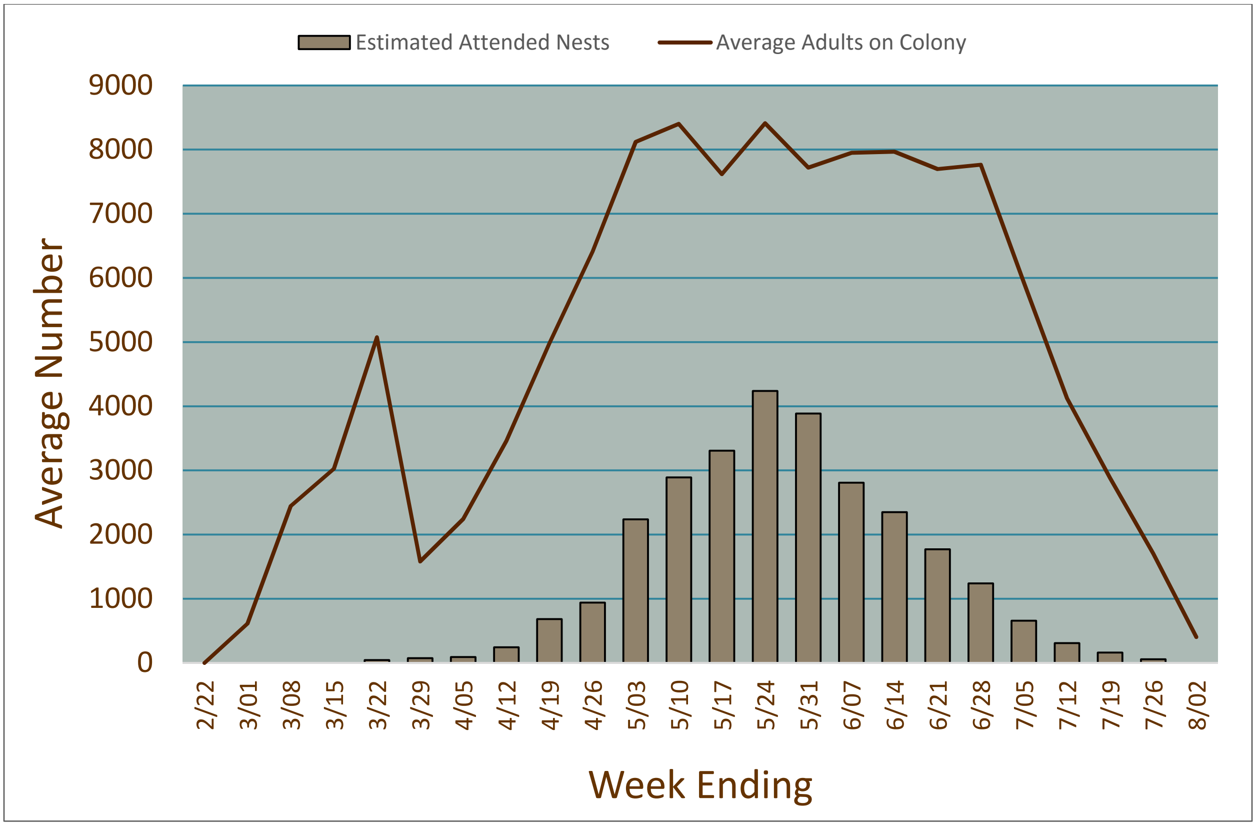


Figure 4. Weekly estimates from the ground of the numbers of adult gulls and attended gull nests on the Goose Island and the surrounding islets (Potholes Reservoir) during the 2015 breeding seasons.

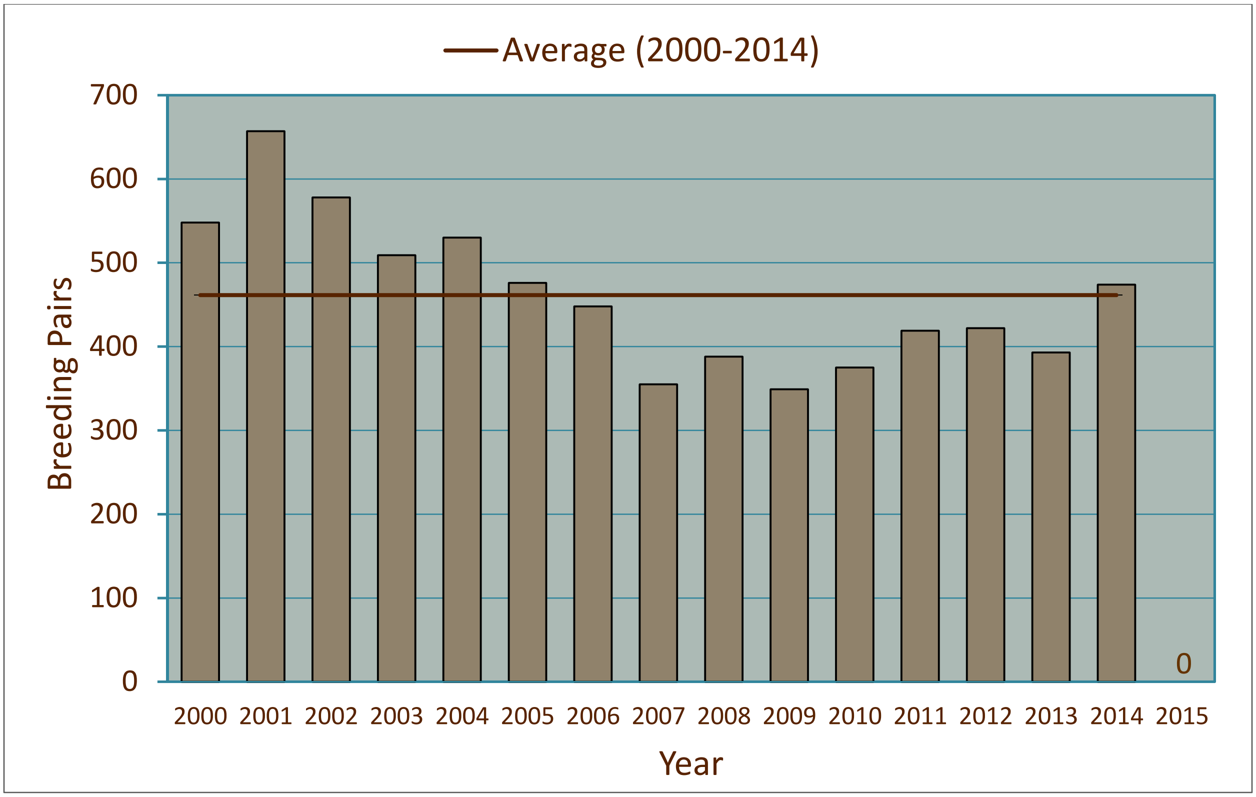


Figure 5. Size of the Caspian tern breeding colony (number of breeding pairs) on Crescent Island in the mid-Columbia River during 2000-2015.

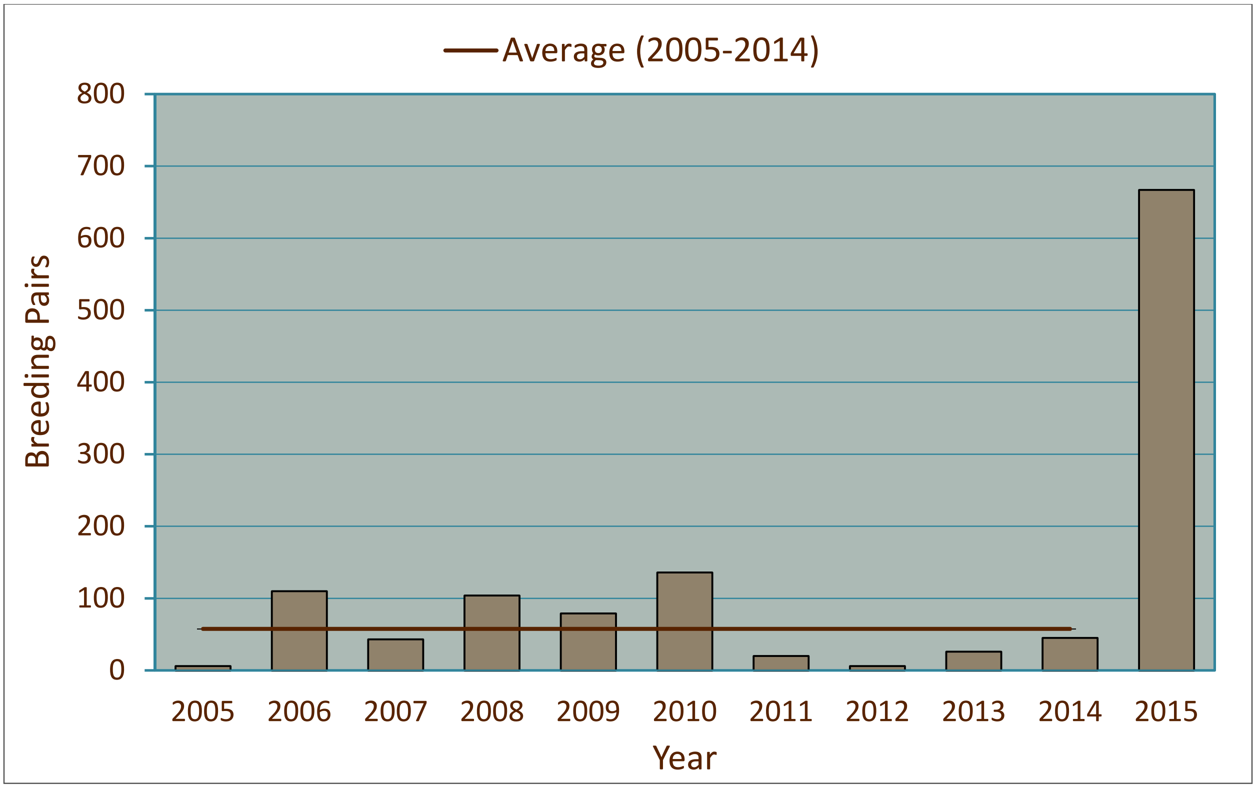


Figure 6. Size of the Caspian tern breeding colony (number of breeding pairs) at the Blalock islands complex in the mid-Columbia River during 2005-2015.

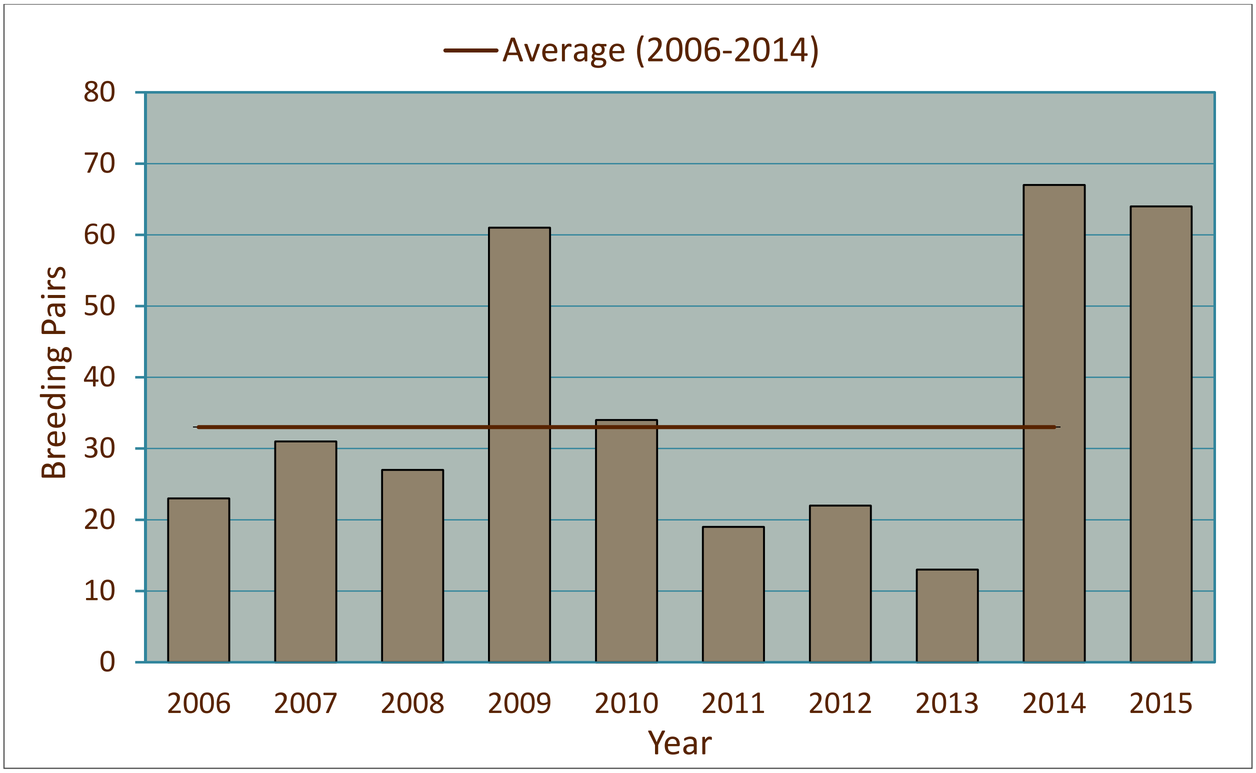


Figure 7. Size of the Caspian tern breeding colony (number of breeding pairs) at Twinning Island in Banks Lake during 2006-2015. In 2005, Caspian terns nested on two islands in Banks Lake (Twinning and Goose islands), and colony size was estimated to be less than 10 breeding pairs at each site.

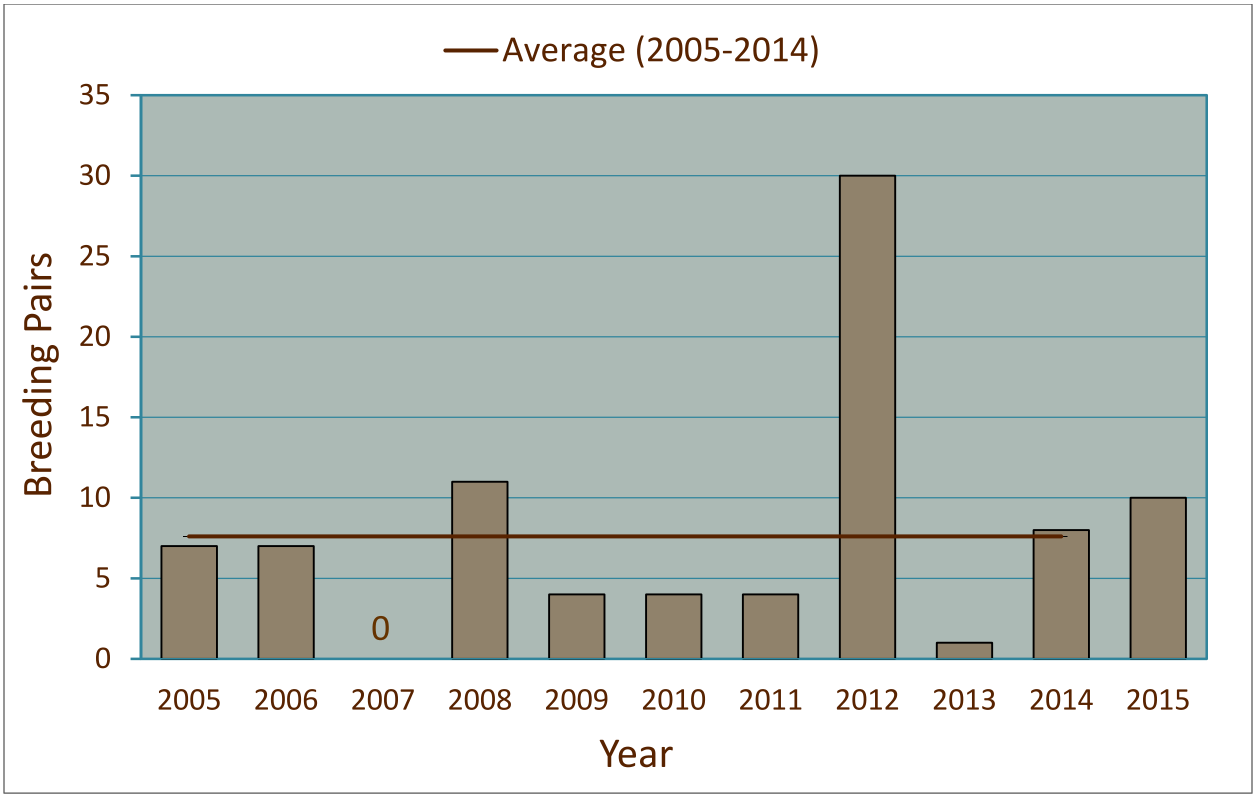


Figure 8. Size of the Caspian tern breeding colony (number of breeding pairs) at Harper Island in Sprague Lake during 2005-2015. Caspian terns did not attempt to nest on Harper Island in 2007.

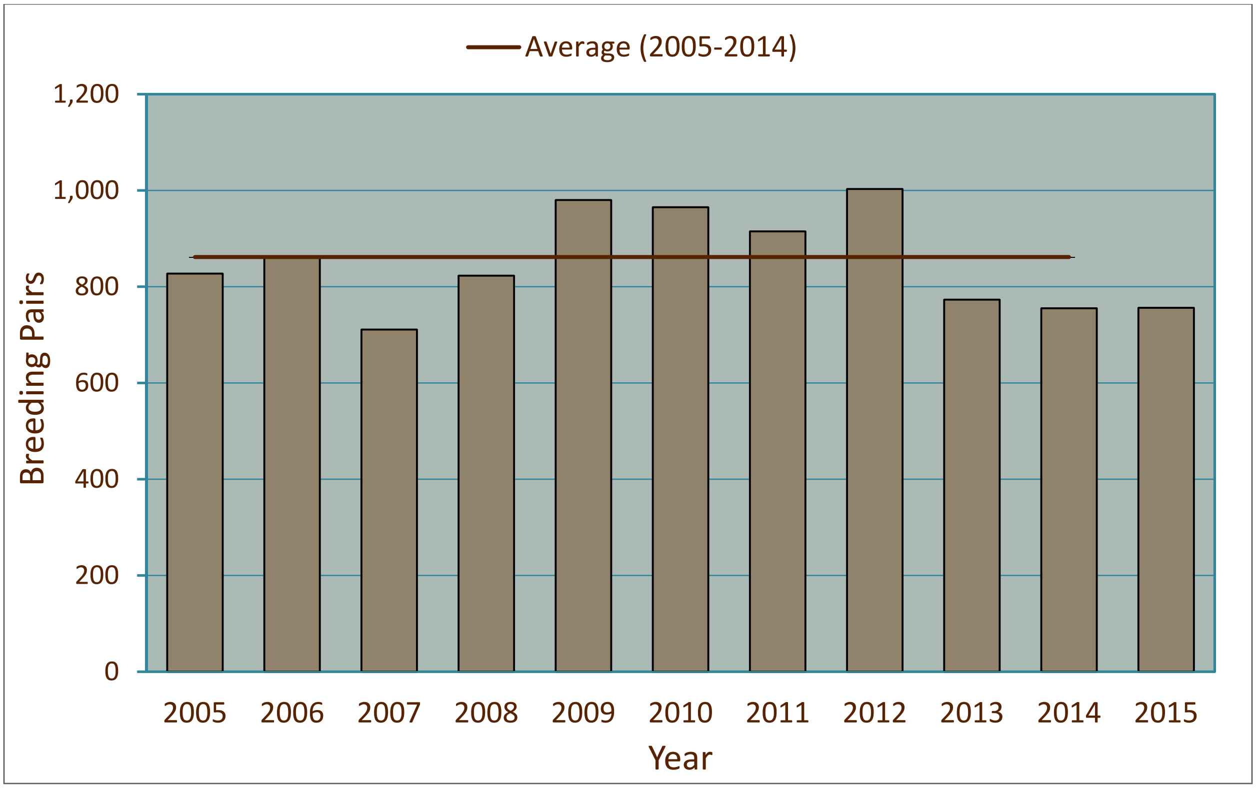


Figure 9. Total numbers of Caspian tern breeding pairs nesting at all known colonies in the Columbia Plateau region during 2005-2015.

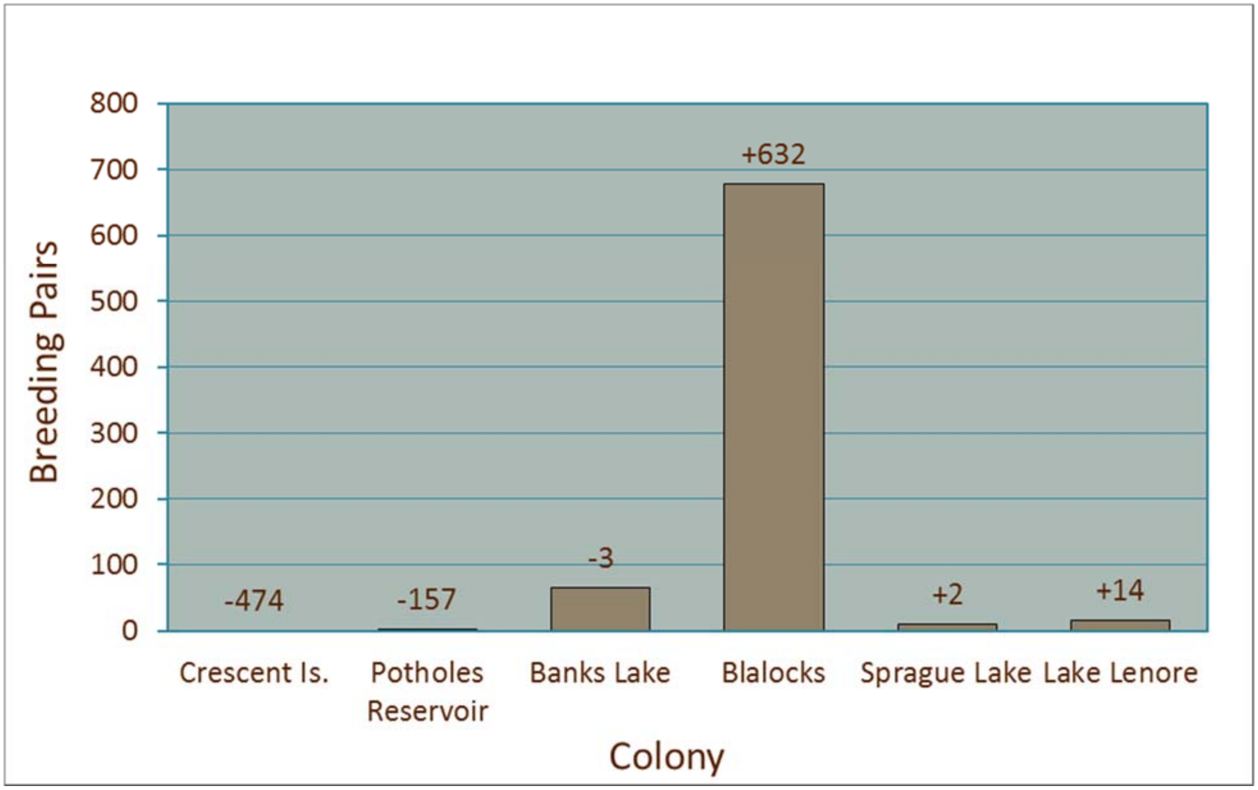


Figure 10. Sizes of Caspian tern breeding colonies (numbers of breeding pairs) in the Columbia plateau region during the 2015 breeding season. Numbers over each bar indicate the change in colony size in 2015 compared to the previous year.

TABLES

Table 1. Summary of sites where Caspian terns were detected during aerial surveys in 2015 along the Columbia and Snake Rivers and on the Columbia River Plateau within tern foraging range (~90 km) of the Federal Columbia River Power System.

Columbia Plateau (off the Columbia River)

Survey Date	Site Name	Prospective Site	Adult Count	Attended Nest Count	Substrate	Breeding Activity	Latitude/ Longitude
25-Jun	Goose Island Colony Area	No	2	2	Upland	Attended Nest	46.985620 -119.310954
25-Jun	Goose Island South East Main	No	13	0	Sand/Beach	Loafing	46.985597 -119.309579
24-Jun	North Potholes Islands	No	33	0	Sand	Loafing	47.031785 -119.319225
25-Jun	Southeast Potholes Reservoir	No	39	0	Sand	Loafing	46.990178 -119.264736
23-Apr	Marsh Unit 1	No	35	0	Mudflat	Loafing	46.954728 -119.261882
15-May	Marsh Unit 1	No	28	0	Mudflat	Loafing	46.954728 -119.261882
24-Apr	Cow Lake	No	2	0	Gravel Bar	Loafing	47.133419 -118.157216
16-May	Harper Island	Yes	12	3	Upland	Attended Nest	47.248105 -118.085808
25-Jun	Harper Island	Yes	3	1	Upland	Attended Nest	47.248105 -118.085808
24-Jun	Lenore Lake	Yes	29	16	Upland	Attended Nest	47.479995 -119.523975

23-Apr	Twinning Island	Yes	17	1	Rock	Attended Nest	47.625266 -119.30265
15-May	Twinning Island	Yes	131	64	Upland	Attended Nest	47.625266 -119.30265

Mid-Columbia River

Survey Date	Site Name	Prospective Site	Adult Count	Attended Nest Count	Substrate	Breeding Activity	Latitude/ Longitude
23-Apr	Badger Island	Yes	2	0	Gravel Bar	Loafing	46.113546 -118.940861
23-Apr	Blalock Islands-Long Island	Yes	200	NA	Gravel Bar	Attended Nest	45.895579 -119.645708
15-May	Blalock Islands-Long Island	Yes	550	NA	Gravel Bar	Attended Nest	45.895579 -119.645708
24-Jun	Blalock Islands-Long Island	Yes	200	NA	Gravel Bar	Attended Nest	45.895579 -119.645708
23-Apr	Blalock Islands-Middle Island	Yes	175	NA	Gravel Bar	Attended Nest	45.895385 -119.646652
15-May	Blalock Islands-Middle Island	Yes	350	NA	Gravel Bar	Attended Nest	45.895385 -119.646652
24-Jun	Blalock Islands-Middle Island	Yes	100	NA	Gravel Bar	Attended Nest	45.895385 -119.646652
23-Apr	Blalock Islands-Southern Island	Yes	12	NA	Gravel Bar	Attended Nest	45.894784 -119.650418
15-May	Blalock Islands-Southern Island	Yes	150	NA	Gravel Bar	Attended Nest	45.894784 -119.650418
23-Apr	Blalock Islands-Sand Island (Beach)	Yes	138	0	Sand	Loafing	45.897132 -119.636768
23-Apr	Blalock Islands-Sand Island (Downstream Tip)	Yes	27	0	Gravel Bar	Loafing	45.890150 -119.644243

15-May	Blalock Islands-Sand Island (Beach)	Yes	98	0	Sand	Loafing	45.897132 -119.636768
15-May	Blalock Islands-Sand Island (Downstream Tip)	Yes	41	0	Gravel Bar	Loafing	45.890150 -119.644243
24-Jun	Blalock Islands-Sand Island (Beach)	Yes	10	0	Sand	Attended Nest	45.897132 -119.636768
24-Jun	Blalock Islands-Rock Island	Yes	1	0	Gravel Bar	Loafing	45.909611 -119.628697
15-May	Blalock Islands-Rock Island	Yes	31	0	Gravel Bar	Loafing	45.909611 -119.628697
23-Apr	Paterson Slough Gravel Island	No	7	0	Gravel Bar	Loafing	45.929542 -119.552578
15-May	Paterson Slough Gravel Island	No	13	0	Gravel Bar	Loafing	45.929542 -119.552578
24-Jun	Paterson Slough Peninsula	No	1	0	Gravel Bar	Loafing	45.928490 -119.564637
23-Apr	Desert Aire	No	17	0	Mudflat	Loafing	46.695332 -119.944505
15-May	Desert Aire	No	54	0	Mudflat	Loafing	46.695332 -119.944505
24-Jun	Desert Aire	No	4	0	Mudflat	Loafing	46.695332 -119.944505
23-Apr	Foundation Island-Downstream Tip	Yes	5	0	Gravel Bar	Loafing	46.163842 -118.994773
24-Jun	Foundation Island-Upstream Tip	Yes	10	0	Gravel Bar	Loafing	46.171934 -119.004152
23-Apr	Finley	No	32	0	Gravel Bar	Loafing	46.144038 -118.993622
24-Jun	Finley	No	2	0	Gravel Bar	Loafing	46.144038 -118.993622
23-Apr	Trinadad	No	32	0	Mudflat	Loafing	47.207947 -120.008764

23-Apr	Unnamed Island above Locke Is.	No	35	0	Gravel Bar	Loafing	46.713800 -119.486494
23-Apr	Unnamed Island below White Bluffs	No	25	0	Gravel Bar	Loafing	46.639513 -119.414381
24-Jun	Unnamed Island below White Bluffs	No	19	0	Gravel Bar	Loafing	46.639513 -119.414381
23-Apr	Crow Butte-Upstream Tip	No	65	0	Sand	Loafing	45.854923 -119.803397
15-May	Crow Butte-Upstream Tip	No	42	0	Sand	Loafing	45.854923 -119.803397
24-Jun	Okanogan	No	4	0	Gravel Bar	Loafing	48.100563 -119.715360
23-Apr	Walla Walla River Delta	No	66	0	Mudflat	Loafing	46.070197 -118.915324
15-May	Walla Walla River Delta	No	48	0	Mudflat	Loafing	46.070197 -118.915324
24-Jun	Walla Walla River Delta	No	34	0	Driftwood	Loafing	46.070197 -118.915324
23-Apr	Warehouse Beach Rocks	No	22	0	Rock	Loafing	45.922552 -119.139231
15-May	Warehouse Beach Rocks	No	25	0	Rock	Loafing	45.922552 -119.139231
24-Jun	Warehouse Beach Rocks	No	12	0	Rock	Loafing	45.922552 -119.139231
23-Apr	Yakima River Delta	No	3	0	Sand	Loafing	46.249722 -119.236191
24-Jun	Yakima River Delta-Bateman Island	No	12	0	Sand	Loafing	46.251392 -119.230846
23-Apr	Walling Canyon Island	No	23	0	Rock	Loafing	47.274728 -120.089577
24-Jun	Walling Canyon Island	No	7	0	Rock	Loafing	47.274728 -120.089577

23-Apr	Island Below Wanapum Dam	No	16	0	Gravel Bar	Loafing	46.858176 -119.95998

Snake River

Survey Date	Site Name	Prospective Site	Adult Count	Attended Nest Count	Substrate	Breeding Activity	Latitude/ Longitude
24-Apr	Mouth of Snake River	No	12	0	Gravel Bar	Loafing	46.202800 -119.028002
24-Apr	Almota Island	No	0	0	Gravel Bar	Loafing	46.688905 -117.455804
16-May	Almota Island	No	0	0	Gravel Bar	Loafing	46.688905 -117.455804

Table 2. Results for 75 test plantings of native willows in an experimental plot on Crescent Island in McNary Pool, Columbia River in 2014 - 2015. See text for a detailed description of the five treatments and the criteria used for quantifying the success of each treatment.

Variable Description	Treatment: Two Rivers single cutting soaked		Two Rivers single cutting not soaked		Two Rivers five cuttings soaked		Two Rivers five cuttings not soaked		Crescent Island five cuttings soaked	
Number of plantings	15		15		15		15		15	
Number of cuttings per planting	1		1		5		5		5	
Year	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
Proportion with ≥ 1 sprouted cutting	0.87	-	0.93	-	1	-	1	-	1	-
Proportion with ≥ 1 live leader	0.73	0.40	0.8	0.53	1	0.87	1	0.47	1	0.93
Proportion w/ *Kochia* in growth space	1	0.13	1	0.07	1	0	1	0.13	1	0.13
Proportion w/ *Atriplex* in growth space	1	1	1	1	1	1	1	1	1	1
Average length (cm) of tallest leader	171	168	163	182	209	182	200	161	177	150
Average diam. (mm) of tallest leader	8.6	9.3	8.9	11.6	9.5	10.6	9.6	10	7.9	8.4
# of cuttings with vigor = 3	7	4	8	6	12	4	11	5	12	10
# of cuttings with vigor = 2	2	0	2	2	3	7	3	1	3	3
# of cuttings with vigor = 1	2	2	2	0	0	2	1	1	0	1
# of cuttings with vigor = 0	4	9	3	7	0	2	0	8	0	1
Proportion with signs of herbivory	-	0	-	0	-	0	-	0	-	0
Proportions with insect deformities	-	0.67	-	0.40	-	0.67	-	0.40	-	0.60
Proportion with water stress deformities	-	0.07	-	0.20	-	0.27	-	0.27	-	0.20

Table 3. Weekly estimates of duration (minutes) and average number of Caspian terns hazed during active nest dissuasion activities at locations on Goose Island in 2015. Map 4 indicates the locations where daily counts of Caspian terns were conducted.

Week	Weekly Hazing Effort (m)	Average Hazing Effort (m/d)	Northwest Main	Northeast Main	Southeast Main	South Spit	Southwest Main	West Main	Colony	East Rocks	Northeast Rocks	New East Rocks	Northwest Rocks
3/02–3/08	845	121	0	0	0	0	0	0	0	0	0	0	0
3/09–3/15	610	87	0	0	0	0	0	0	0	0	0	0	0
3/16–3/22	1970	281	0	0	0	0	0	0	0	0	0	0	0
3/23–3/29	2460	351	0	0	0	0	0	0	0	6	0	0	0
3/30–4/05	3245	464	0	0	0	0	0	0	0	8	0	0	0
4/06–4/12	3295	471	0	0	0	1	0	0	0	11	0	0	2
4/13–4/19	2317	331	0	0	0	2	0	0	0	3	5	0	4
4/20–4/26	2027	290	0	0	16	0	5	2	0	14	1	0	5
4/27–5/03	2680	383	0	0	4	0	2	15	0	0	0	0	0
5/04–5/10	2526	361	0	6	0	1	1	12	NA	0	0	0	0
5/11–5/17	1858	265	0	0	4	0	7	1	0	0	0	0	0
5/18–5/24	2379	340	0	0	0	1	0	4	2	0	0	0	0
5/25–5/31	2383	340	0	0	0	0	0	10	3	0	0	0	0
6/01–6/07	3118	445	0	1	4	3	6	17	3	2	0	0	0
6/08–6/14	2746	392	0	2	60	0	9	1	3	5	0	0	0
6/15–6/21	3116	445	0	0	79	0	2	0	2	0	0	0	4
6/22–6/28	2350	336	1	0	74	1	7	1	2	0	0	0	5
6/29–7/05	1651	236	16	1	91	0	43	0	0	0	0	0	4
7/06–7/12	1341	192	6	1	79	0	45	7	0	0	0	0	0
7/13–7/19	852	142	10	10	101	22	13	47	0	0	0	0	6
7/20–7/26	734	105	2	10	132	3	1	0	0	0	0	25	0
7/27–8/02	240	34	0	16	14	0	0	0	0	10	0	63	17

Table 4. Caspian tern eggs collected under permit on Goose Island in 2015.

NestID	Egg #	Date	Time	Country	State	Waterbody	Location	Nest Location
1	1	4/21/2015		USA	WA	Potholes Reservoir	Goose Island	NW Rocks
2	2	4/26/2015	6:15	USA	WA	Potholes Reservoir	Goose Island	SW Tip
3	3	4/26/2015	10:17	USA	WA	Potholes Reservoir	Goose Island	E Rocks
4	4	4/30/2015	6:05	USA	WA	Potholes Reservoir	Goose Island	SW Tip
5	5	4/30/2015	6:05	USA	WA	Potholes Reservoir	Goose Island	SW Tip
6	6	4/30/2015	17:40	USA	WA	Potholes Reservoir	Goose Island	SW Tip
6	7	4/30/2015	17:40	USA	WA	Potholes Reservoir	Goose Island	SW Tip
7	8	5/1/2015	19:03	USA	WA	Potholes Reservoir	Goose Island	SW Tip
8	9	5/1/2015	5:45	USA	WA	Potholes Reservoir	Goose Island	S Gravel Bar
9	10	5/3/2015	17:18	USA	WA	Potholes Reservoir	Goose Island	SW Tip
10	11	5/3/2015	17:18	USA	WA	Potholes Reservoir	Goose Island	SW Tip
11	12	5/4/2015	5:35	USA	WA	Potholes Reservoir	Goose Island	SW Tip
12	13	5/4/2015	5:35	USA	WA	Potholes Reservoir	Goose Island	SW Tip
14	14	5/4/2015	13:08	USA	WA	Potholes Reservoir	Goose Island	SW Tip
15	15	5/6/2015	13:30	USA	WA	Potholes Reservoir	Goose Island	SW Tip
17	16	5/14/2015	17:10	USA	WA	Potholes Reservoir	Goose Island	NW Main
39	17	6/19/2015	13:35	USA	WA	Potholes Reservoir	Goose Island	S Beach

Table 5. Weekly estimates of cumulative duration (minutes) required to deter gulls from landing on Crescent Island in 2015.

Week	Weekly Hazing Effort (m)	Average Hazing Effort (m/d)
3/02–3/08	280	40
3/09–3/15	289	41
3/16–3/22	699	100
3/23–3/29	822	117
3/30–4/05	983	140
4/06–4/12	1361	194
4/13–4/19	1118	160
4/20–4/26	1743	249
4/27–5/03	1802	257
5/04–5/10	936	134
5/11–5/17	188	27
5/18–5/24	147	21
5/25–5/31	0	0
6/01–6/07	0	0
6/08–6/14	0	0
6/15–6/21	0	0
6/22–6/28	0	0
6/29–7/05	0	0
7/06–7/12	0	0
7/13–7/16	0	0

Table 6. Numbers of banded Caspian terns resighted in Potholes Reservoir area in 2015 and the colony locations where they were originally marked with uniquely engraved alphanumeric color bands during 2005-2014. Potholes Reservoir area includes Goose Island, small islands in north Potholes, and a marsh unit in Columbia National Wildlife Refuge.

Colony where banded	Banded as adults	Banded as chicks	Total
Goose Island	119	71	190
Crescent Island	4	13	17
Sheepy Lake	0	4	4
East Sand Island	0	4	4
Port of Bellingham	0	2	2
Brooks Island	0	2	2
Crump Lake	0	2	2
Malheur Lake	0	1	1
Total	**123**	**99**	**222**

Table 7. Numbers of banded Caspian terns resighted at Blalock Islands in 2015 and the colony locations where they were originally marked with uniquely engraved alphanumeric color bands during 2005-2014.

Colony banded	Banded as adults	Banded as chicks	Total
Crescent Island	151	160	311
Goose Island	105	71	176
East Sand Island	1	11	12
Port of Bellingham	0	6	6
Sheepy Lake	0	6	6
Malheur Lake	0	3	3
Crump Lake	0	1	1
Total	**257**	**258**	**515**

Table 8. Numbers of banded Caspian terns seen at Crescent Island in 2014 and resighted in 2015 at breeding or non-breeding sites. Terns were banded in 2005-2014 with color bands engraved with unique alphanumeric codes. A total of 262 banded terns were seen at Crescent Island in 2014 and resighted in 2015 elsewhere; some of them were resighted at multiple locations in 2015.

Location where resighted in 2015	Banded as adults	Banded as chicks	Total
Blalock Islands	154	86	240
Potholes Reservoir area*	25	6	31
East Sand Island	21	6	27
Malheur Lake	12	3	15
Twinning Island	8	2	10
Tule Lake	4	4	8
McNary Pool**	1	2	3
East Link Island (Summer Lake)	2	1	3
Lake Lenore	2	0	2
Rat Island (Salish Sea)	0	2	2
Total	**229**	**112**	**341**

**   Potholes Reservoir area includes Goose Island, Islands in North Potholes Reservoir, and Marsh Unit 1 in Columbia Basin National Wildlife Refuge.*
*** McNary Pool includes Borgans Island, mouth of Snake River, and Finley Island.*

Table 9. Numbers of banded Caspian terns seen at Goose Island in 2014 and resighted in 2015 at breeding or non-breeding sites. Terns were banded in 2005-2014 with color bands engraved with unique alphanumeric codes. A total of 262 banded terns were seen at Goose Island in 2014 and resighted in 2015 again at Goose Island or elsewhere; some of them were resighted at multiple locations in 2015.

Location resighted in 2015	Banded as adults	Banded as chicks	Total
Potholes Reservoir area*	100	45	145
Blalock Islands	86	40	126
Twinning Island	27	9	36
Tule Lake	9	8	17
East Sand Island	8	8	16
Malheur Lake	14	2	16
Rat Island (Salish Sea)	2	4	6
Lenore Lake	3	2	5
Desert Aire (Priest Rapids)	2	0	2
Everett (Coastal Washington)	2	1	3
Rice Island (Columbia River estuary)	0	1	1
Sheepy Lake	1	0	1
Total	**254**	**120**	**374**

* Potholes Reservoir area includes Goose Island, Islands in North Potholes Reservoir, and *Marsh Unit 1 in Columbia Basin National Wildlife Refuge.*

Table 10. Inter-colony movement probabilities of Caspian terns between 2014 and 2015. Data used in movement probability estimates were from terns banded as adults during 2005-2014 and re-sighted during 2006-2015. The numbers of individuals that moved between 2014 and 2015 were estimated from movement probabilities between those years multiplied by estimated numbers of adults present at source regions in 2014.

Source colony	Receiving colony	Movement probabilities (%)	Estimated number of individuals that moved
Columbia River estuary	Columbia Plateau	1.4	172
Columbia River estuary	Corps-constructed islands	<0.0001	Below detectable level
Columbia Plateau	Columbia River estuary	4.4	67
Columbia Plateau	Corps-constructed islands	0.7	11
Corps-constructed islands	Columbia River estuary	5.0	79
Corps-constructed islands	Columbia Plateau	18.7	293

Table 11. Colony sizes and estimated predation rates (95% Credibility Intervals) by Caspian terns on ESA-listed salmonid populations (ESU/DPS) originating from the Snake River (SR) and Upper Columbia River (UCR) during 2007-2014. NA denotes colonies that were not scanned for PIT tags in a given year or where sample sizes of PIT-tagged smolts interrogated passing dams were too small (< 500) to generate reliable predation rate estimates. Asterisks denotes that the colony was managed as part of Inland Avian Predation Management Plan that year.

		ESU/DPS-specific Predation Rates by Goose Island Caspian Terns in Potholes Reservoir					
Year	Colony Size	UCR Steelhead	UCR Spring Chinook	SR Steelhead	SR Spr/Sum Chinook	SR Fall Chinook	SR Sockeye
2007	282	15.3% (9.8-27.7)	- NA -	0.1% (0-0.2)	<0.1%	0.3% (0-1.1)	- NA -
2008	293	11.1% (8.6-16.4)	- NA -	<0.1%	<0.1%	<0.1%	0.4% (0-1.6)
2009	487	22.6% (17.2-33.7)	5.5% (2.7-10.7)	0.1% (0-0.1)	<0.1%	<0.1%	0.1% (0-0.4)
2010	416	14.6% (11-21.8)	2.0% (0.7-4.4)	<0.1%	<0.1%	<0.1%	0.3% (0-1.4)
2011	422	12.9% (9.6-19.6)	0.6% (0.1-1.9)	<0.1%	<0.1%	<0.1%	<0.1%
2012	463	18.4% (13.5-28.5)	2.6% (1.2-5.4)	0.2% (0.1-0.4)	<0.1%	<0.1%	0.1% (0-0.4)
2013	340	14.8% (11.4-21.6)	2.5% (1.1-5.2)	0.1% (0-0.3)	<0.1%	0.1% (0-0.3)	0.1% (0-0.5)
2014*	159	2.9% (1.9-5.1)	0.6% (0.1-2.2)	<0.1%	<0.1%	<0.1%	<0.1%
Average		**14.3% (12.7-16.3)**	**2.1% (1.4-2.9)**	**<0.1%**	**<0.1%**	**<0.1%**	**<0.1%**
Average Per Capita		**0.039% (0.034-0.045)**	**0.003% (0.001-0.004)**	**<0.001%**	**<0.001%**	**<0.001%**	**<0.001%**

		ESU/DPS-specific Predation Rates by Crescent Isalnd Caspian Terns in McNary Reservoir					
Year	Colony Size	UCR Steelhead	UCR Spring Chinook	SR Steelhead	SR Spr/Sum Chinook	SR Fall Chinook	SR Sockeye
2007	355	2.5% (1.7-3.8)	- NA -	3.9% (3.1-5.6)	0.4% (0.3-0.6)	0.9% (0.4-1.7)	- NA -
2008	388	2.9% (2.1-4.3)	- NA -	5.9% (4.7-8.5)	0.9% (0.7-1.3)	1.6% (1.2-2.3)	1.7% (0.6-3.7)
2009	349	2.3% (1.7-3.5)	0.2% (0-1.2)	4.6% (3.7-6.6)	1.5% (1.1-2.2)	1.1% (0.8-1.6)	1.0% (0.5-1.7)
2010	375	1.8% (1.3-2.7)	0.9% (0.3-2.3)	4.0% (3.1-5.9)	0.4% (0.3-0.7)	1.0% (0.7-1.4)	1.5% (0.5-3.5)
2011	419	2.4% (1.8-3.6)	0.5% (0.1-1.2)	2.7% (2.1-4)	0.7% (0.5-1.0)	0.5% (0.4-0.8)	0.7% (0.5-1.1)
2012	422	1.2% (0.8-2.0)	0.2% (0-0.8)	2.8% (2.1-4.1)	0.6% (0.4-0.9)	0.5% (0.4-0.8)	1.3% (0.9-2.2)
2013	393	2.9% (2.1-4.3)	0.4% (0.1-1.2)	2.9% (2.2-4.3)	0.5% (0.4-0.8)	0.7% (0.4-1.1)	0.6% (0.2-1.4)
2014	474	3.4% (2.5-4.8)	0.7% (0.2-2.1)	4.7% (3.7-6.9)	0.5% (0.3-0.7)	0.5% (0.3-0.8)	0.7% (0.4-1.3)
Average		**2.4% (2.2-2.8)**	**0.5% (0.3-0.8)**	**3.9% (3.5-4.6)**	**0.7% (0.6-0.8)**	**0.8% (0.7-1.0)**	**1.1% (0.7-1.3)**
Average Per Capita		**0.006% (0.005-0.008)**	**0.002% (0.001-0.003)**	**0.011% (0.009-0.013)**	**0.002% (0.001-0.002)**	**0.002% (0.002-0.003)**	**0.003% (0.002-0.004)**

Year	Colony Size	UCR Steelhead	UCR Spring Chinook	SR Steelhead	SR Spr/Sum Chinook	SR Fall Chinook	SR Sockeye
		ESU/DPS-specific Predation Rate by Blalock Island Caspian Terns in John Day Reservoir					
2007	43	1.0% (0.6-1.7)	<0.1%	0.9% (0.6-1.4)	<0.1%	0.1% (0-0.2)	- NA -
2008	104	0.7% (0.4-1.2)	0.1% (0-0.2)	0.8% (0.6-1.2)	0.1% (0.1-0.2)	<0.1%	0.3% (0-2)
2009	79	0.5% (0.3-1.0)	0.2% (0.1-0.5)	0.6% (0.4-0.9)	0.3% (0.2-0.4)	<0.1%	<0.1%
2010	136	0.9% (0.6-1.6)	0.1% (0-0.1)	0.9% (0.7-1.4)	0.1% (0-0.1)	<0.1%	0.2% (0-0.6)
2011	20	0.1% (0-0.3)	<0.1%	0.1% (0.1-0.2)	0.1% (0-0.1)	0.1% (0.1-0.2)	0.3% (0.1-0.8)
2012	6	- NA -	- NA -	- NA -	- NA -	- NA -	- NA -
2013	26	0.2% (0-0.5)	<0.1%	0.1% (0-0.2)	<0.1%	0.1% (0-0.1)	<0.1%
2014	45	0.6% (0.3-1.2)	0.2% (0.1-0.4)	0.4% (0.2-0.7)	0.1% (0.1-0.2)	0.3% (0.2-0.5)	0.4% (0.1-1.1)
Average		**0.6% (0.4-0.8)**	**<0.1%**	**0.6% (0.5-0.7)**	**0.1% (0-0.1)**	**<0.1%**	**0.3% (0.2-0.4)**
Average Per Capita		**0.009% (0.007-0.012)**	**0.001% (0.000-0.002)**	**0.007% (0.005-0.009)**	**0.002% (0.001-0.003)**	**0.002% (0.001-0.004)**	**0.004% (0.001-0.011)**

Table 12. Predicted predation rates (95% Prediction Intervals) for different Caspian tern colony sizes. Predicted predation rates are based on average per capita predation rates during 2007-2014 (see Table 1). Predicted predation rates are shown for ESA-listed salmonid populations (ESU/DPS) originating from the Snake River (SR) and Upper Columbia River (UCR). Highlighted (dark blue rows) predation rates are based on actual Caspian tern colony counts in 2015. All other estimates are for hypothetical colony sizes. An asterisk indicates entries exceeding the empirical range of data collected during 2007-2014, resulting in considerable uncertainty in the associated predicted predation rate in 2015. Due to management activities, no directly comparable estimate of peak colony size was available for terns at Goose Island in 2015, so alternative measures of colony size were used (see Methods).

Colony Size	ESU/DPS-specific Predation Rates by Goose Island Caspian Terns in Potholes Reservoir							
	UCR Steelhead		UCR Spring Chinook		SR Steelhead	SR Spr/Sum Chinook	SR Fall Chinook	SR Sockeye
14 [1]	***0.5%***	***(0.5-0.6)***	***0.0%***	***(0-0.1)***	**<0.1%**	**<0.1%**	**<0.1%**	**<0.1%**
20	0.8%	(0.7-0.9)	0.1%	(0-0.1)	<0.1%	<0.1%	<0.1%	<0.1%
39 [2]	***1.5%***	***(1.3-1.8)***	***0.1%***	***(0.1-0.2)***	**<0.1%**	**<0.1%**	**<0.1%**	**<0.1%**
40	1.6%	(1.4-1.8)	0.1%	(0.1-0.2)	<0.1%	<0.1%	<0.1%	<0.1%
60	2.3%	(2-2.7)	0.2%	(0.1-0.3)	<0.1%	<0.1%	<0.1%	<0.1%
80	3.1%	(2.7-3.6)	0.2%	(0.1-0.4)	<0.1%	<0.1%	<0.1%	<0.1%
100	3.9%	(3.4-4.5)	0.3%	(0.2-0.5)	<0.1%	<0.1%	<0.1%	<0.1%
150	5.9%	(5.1-6.8)	0.4%	(0.2-0.7)	<0.1%	<0.1%	<0.1%	<0.1%
200	7.8%	(6.8-9.1)	0.6%	(0.3-0.9)	<0.1%	<0.1%	<0.1%	<0.1%
250	9.8%	(8.5-11.3)	0.7%	(0.4-1.2)	<0.1%	<0.1%	<0.1%	<0.1%
300	11.7%	(10.2-13.6)	0.8%	(0.4-1.4)	<0.1%	<0.1%	<0.1%	<0.1%
350	13.7%	(11.9-15.9)	1.0%	(0.5-1.6)	<0.1%	<0.1%	<0.1%	<0.1%
400	15.6%	(13.6-18.1)	1.1%	(0.6-1.9)	<0.1%	<0.1%	<0.1%	0.1% (0-0.2)
450	17.6%	(15.3-20.4)	1.3%	(0.7-2.1)	<0.1%	<0.1%	<0.1%	0.1% (0-0.2)
500	19.5%	(17-22.7)	1.4%	(0.7-2.3)	<0.1%	<0.1%	<0.1%	0.1% (0-0.2)

[1] *Average daily number of adult terns observed during the smolt outmigration period (see Methods)*

[2] *Number of nests initiated (see Methods)*

Colony Size	ESU/DPS-specific Predation Rates by Crescent Island Caspian Terns in McNary Reservoir											
	UCR Steelhead		UCR Spring Chinook		SR Steelhead		SR Spr/Sum Chinook		SR Fall Chinook		SR Sockeye	
0	**<0.1%**		**<0.1%**		**<0.1%**		**<0.1%**		**<0.1%**		**<0.1%**	
20	0.1%	(0.1-0.2)	<0.1%		0.2%	(0.2-0.3)	<0.1%		<0.1%		<0.1%	
40	0.3%	(0.2-0.3)	<0.1%		0.4%	(0.4-0.5)	<0.1%		<0.1%		0.1%	(0.1-0.2)
60	0.4%	(0.3-0.5)	0.1%	(0-0.2)	0.6%	(0.5-0.8)	<0.1%		0.1%	(0.1-0.2)	0.2%	(0.1-0.2)
80	0.5%	(0.4-0.6)	0.1%	(0.1-0.2)	0.9%	(0.7-1)	0.1%	(0.1-0.2)	0.2%	(0.2-0.3)	0.2%	(0.2-0.3)
100	0.6%	(0.5-0.8)	0.2%	(0.1-0.3)	1.1%	(0.9-1.3)	0.2%	(0.1-0.2)	0.2%	(0.2-0.3)	0.3%	(0.2-0.4)
150	1.0%	(0.8-1.2)	0.2%	(0.1-0.4)	1.6%	(1.4-1.9)	0.2%	(0.2-0.3)	0.4%	(0.3-0.5)	0.4%	(0.3-0.6)
200	1.3%	(1.1-1.6)	0.3%	(0.1-0.6)	2.2%	(1.8-2.6)	0.3%	(0.3-0.4)	0.5%	(0.4-0.6)	0.6%	(0.4-0.8)
250	1.6%	(1.4-1.9)	0.4%	(0.2-0.7)	2.7%	(2.3-3.2)	0.4%	(0.3-0.5)	0.6%	(0.5-0.8)	0.7%	(0.5-1)
300	1.9%	(1.6-2.3)	0.5%	(0.2-0.9)	3.2%	(2.7-3.9)	0.5%	(0.4-0.6)	0.7%	(0.6-0.9)	0.8%	(0.6-1.2)
350	2.3%	(1.9-2.7)	0.5%	(0.2-1)	3.8%	(3.2-4.5)	0.6%	(0.5-0.7)	0.9%	(0.7-1.1)	1.0%	(0.7-1.4)
400	2.6%	(2.2-3.1)	0.6%	(0.3-1.2)	4.3%	(3.6-5.2)	0.6%	(0.5-0.8)	1.0%	(0.8-1.2)	1.1%	(0.8-1.6)
450	2.9%	(2.5-3.5)	0.7%	(0.3-1.3)	4.8%	(4.1-5.8)	0.7%	(0.6-0.9)	1.1%	(0.9-1.4)	1.3%	(0.9-1.8)
500	3.2%	(2.7-3.9)	0.8%	(0.3-1.5)	5.4%	(4.5-6.5)	0.8%	(0.7-1)	1.2%	(1-1.6)	1.4%	(1-2)

Colony Size	ESU/DPS-specific Predation Rate by Blalock Island Caspian Terns in John Day Reservoir											
	UCR Steelhead		UCR Spring Chinook		SR Steelhead		SR Spr/Sum Chinook		SR Fall Chinook		SR Sockeye	
20	0.2%	(0.1-0.3)	<0.1%		0.1%	(0.1-0.2)	<0.1%		<0.1%		0.1%	(0-0.2)
40	0.4%	(0.3-0.5)	<0.1%		0.3%	(0.2-0.4)	<0.1%		<0.1%		0.2%	(0-0.5)
60	0.6%	(0.4-0.8)	<0.1%		0.4%	(0.4-0.5)	0.1%	(0.1-0.2)	0.1%	(0.1-0.2)	0.2%	(0.1-0.7)
80	0.7%	(0.6-1)	0.1%	(0-0.2)	0.6%	(0.4-0.7)	0.2%	(0.1-0.2)	0.1%	(0.1-0.3)	0.3%	(0.1-0.9)
100	0.9%	(0.7-1.3)	0.1%	(0-0.2)	0.7%	(0.6-0.9)	0.2%	(0.1-0.3)	0.2%	(0.1-0.4)	0.4%	(0.1-1.1)
200*	1.9%	(1.4-2.6)	0.2%	(0.1-0.4)	1.4%	(1.2-1.8)	0.4%	(0.3-0.6)	0.4%	(0.2-0.7)	0.8%	(0.2-2.3)
300*	2.8%	(2.1-3.8)	0.2%	(0.1-0.6)	2.2%	(1.8-2.7)	0.6%	(0.4-0.9)	0.6%	(0.3-1.1)	1.2%	(0.3-3.4)
400*	3.7%	(2.9-5.1)	0.3%	(0.1-0.8)	2.9%	(2.2-3.6)	0.8%	(0.6-1.2)	0.7%	(0.3-1.5)	1.6%	(0.4-4.6)
500*	4.7%	(3.6-6.4)	0.4%	(0.1-1)	3.6%	(2.9-4.5)	1.0%	(0.7-1.4)	0.9%	(0.4-1.8)	2.0%	(0.4-5.7)
600*	5.6%	(4.3-7.7)	0.5%	(0.2-1.3)	4.3%	(3.4-5.4)	1.2%	(0.9-1.7)	1.1%	(0.5-2.2)	2.4%	(0.5-6.8)
677*	***6.3%***	***(4.8-8.7)***	***0.5%***	***(0.2-1.4)***	***4.8%***	***(3.9-6.1)***	***1.4%***	***(1-1.9)***	***1.2%***	***(0.6-2.4)***	***2.7%***	***(0.6-7.7)***
700*	6.6%	(5-8.9)	0.6%	(0.2-1.5)	5.0%	(4-6.3)	1.5%	(1-2)	1.3%	(0.6-2.6)	2.8%	(0.6-8)

APPENDIX A: BEST MANAGEMENT PRACTICES

The goal of management on Goose Island and Crescent Island (hereafter referred to collectively as the "managed islands") is to prevent any more than 40 pairs of Caspian terns from nesting on either island. In order to achieve this goal, the objective in 2015 is to dissuade all Caspian terns from nesting on the two managed islands. Caspian tern nesting is defined as terns laying one or more eggs in a nest scrape.

A strategy the federal management agencies (Corps of Engineers, Bureau of Reclamation, and U.S. Fish and Wildlife Service) have advocated for achieving the above objective is to try to prevent or delay all gulls from nesting on the managed islands. The strategy is based on the supposition that once gulls lay eggs on the managed islands, Caspian terns that subsequently attempt to nest near active gull nests cannot be hazed without causing gull nests to fail, because nests of gulls flushed during tern hazing will be at risk of having their eggs depredated by other gulls. The U.S. Fish and Wildlife Service has stated that, while it is prepared to issue a permit to take a limited number of Caspian tern eggs on the managed islands (< 200 eggs per island), in the event that Caspian terns successfully lay eggs, the agency cannot issue a permit for incidental take of other migratory bird species, including incidental take of gull eggs during tern hazing activities. Therefore, by preventing or delaying gull nesting on the managed islands, the potential for active gull nests (those with eggs) to shield Caspian tern nests from hazing will be reduced. Similarly, Canada geese, herons, and egrets have nested on one or both of the managed islands in previous years and best management practices (BMPs) have been developed for these species as well.

The difficulty in dissuading all gulls from nesting on the managed islands using passive dissuasion (landscape fabric fences or stakes, ropes, and flagging) and human hazing techniques has been communicated to the federal management agencies. Prior to the waterbird breeding season, large areas of passive dissuasion will be installed on each island at the direction of the management agencies to make the islands less attractive to nesting Caspian terns. Observations on Goose Island in 2014 indicated that, unlike Caspian terns, ring-billed gulls and California gulls were not responsive to passive dissuasion; the two gull species readily entered areas of passive dissuasion and initiated nests. In addition, gulls tended to acclimate more readily than Caspian terns to repeated human hazing, and quickly returned to their nest sites after flushing due to human hazing.

The Bureau of Reclamation (owner of Goose Island) is planning to test additional management actions for precluding gulls and terns from nesting on Goose Island in 2015 and 2016, including propane cannons, water cannons, predator decoys, bird distress call systems, and windsocks. These test actions are limited in use and until gulls begin laying eggs on the island and will be managed directly by Reclamation. Crepuscular and nocturnal hazing using bright lights and lasers to enhance the efficacy of passive dissuasion and daytime human hazing have been authorized for use again this season under Reclamation's NEPA Categorical Exclusion for test actions noted above. These techniques showed some promise for delaying the initiation of gull nests on Goose Island in 2014 by causing island abandonment by gulls each night during the early stages of the breeding season (before egg-laying commences). However, once gull nests with eggs are confirmed, crepuscular or night-time hazing that may lead to overnight island abandonment will be discontinued to avoid egg loss during the nocturnal absence of nesting adults. Weather-permitting, personnel will stay overnight in portable buildings on the managed islands so they can haze any gulls that attempt to spend the night on the islands pre-egg-laying, and to use bright lights and lasers to dissuade gulls that attempt to return to the island at first light.

The passive dissuasion (stakes, ropes, and flagging at both islands and fabric fencing on Crescent Island) will be installed to cover essentially all of the suitable and marginally suitable Caspian tern nesting habitat on the managed islands, and the area where passive dissuasion has been deployed will be the primary focus of gull hazing. Fixed and portable observation blinds may also be used to dissuade gull nesting using lasers, especially gulls that attempt to nest in any interior areas of either of the islands.

Results of passive and active nest dissuasion at Goose Island in 2014 indicated that even with intensive human hazing, gulls are likely to ultimately establish nests and lay eggs on the managed islands, both within and outside the passive dissuasion areas, but it is unlikely that Caspian terns will be decoyed into areas of passive dissuasion by nesting gulls. Instead, Caspian terns are more likely to initiate nests on marginal habitat that lies outside areas covered by passive dissuasion so more passive dissuasion is being added to Goose Island for a total of ca. 3.5 acres of rope and flagging as a well as double roping to the perimeter of the dissuaded areas.

We have also developed best management practices (BMPs) for minimizing disturbance during hazing of gulls and Caspian terns to other migratory bird species that nest on the two managed islands. Canada geese are known to nest on both managed islands, and great blue herons, black-crowned night-herons, and great egret are known to nest on Crescent Island. Flushing any of these non-target species from their nests has the potential to result in egg loss due to egg predators. Canada geese generally nest on the ground, whereas herons and egrets generally build stick nests in trees and tall shrubs. The areas where herons and egrets have nested previously on Crescent Island are in the densely-vegetated interior of the island; these areas are not used by nesting gulls or Caspian terns and are unsuitable nesting habitat for either gulls or terns. Consequently, these areas of the island will not be hazed to prevent or delay gull nesting, and will be avoided to minimize disturbance to non-target nesting herons and egrets.

Using the same techniques described for Caspian terns and gulls, geese, herons, and egrets will be dissuaded from establishing new nests on the portions of the managed islands where gull and tern hazing will be conducted. For any goose, heron, or egret nests with eggs, or nests of other non-target migratory birds that may be discovered during the process of hazing Caspian terns or gulls, practices to reduce the chances of egg loss are described in detail below.

Early in the pre-breeding period, before behaviors associated with imminent egg-laying are widespread (e.g., nest-building, copulation), human hazing of gulls will consist of walk-throughs of the island to flush any and all gulls that are present. Twice each day, a 2-person crew will conduct a walk-through of each managed island. These walk-throughs will occur early in the day (before 10:00 am) and late in the day (after 3:00 pm), weather permitting. During each walk-through, the locations of any gull aggregations will be mapped on a diagram of the island. Once per week, the locations of gulls by species (ring-billed gulls or California gulls) will be mapped. Any areas where gulls are holding territories or engaged in pre-laying behaviors (i.e., courtship, territorial display, copulation, and nest-building) will also be marked on the map. If possible, the species of gull (California or ring-billed) that is engaged in pre-laying behaviors will be recorded. All gulls on the island will be flushed at least once during each walk-through event, unless gulls are known or suspected of attending eggs.

Prior to each of the early-day walk-throughs, the crew will boat around each managed island and estimate the numbers of all gulls and Caspian terns on the island, as well as the numbers of gulls and Caspian terns roosting on any emergent rocks nearby. Counts will be completed relatively quickly (< 30 min). When large numbers of gulls are present (thousands), it will be acceptable to estimate the number of gulls present by counting in the 100's, and there will be no attempt to distinguish between the two gull species in the numbers of gulls present. Gull counts/estimates will be entered into the waterbird survey PDA application and reported in the weekly report to the Corps and Reclamation. An estimate of the proportion of each gull species on each managed island and how gull numbers were estimated (e.g., counted in 100's) will be included. Counts of Caspian terns observed on each island will be entered into the Caspian tern PDA application and reported in the weekly report to the Corps and Reclamation. If Caspian terns are likely present in areas difficult to survey from the boat, follow-up counts of Caspian terns will be conducted from blinds adjacent to the former colony areas, or other suitable vantage. For extended observations of Caspian terns from a blind, we will include counts upon arrival and before departure, and will include the maximum number of Caspian terns observed in the "notes" section of the tern PDA application. We will update or replace boat-based counts/estimates of gulls and Caspian terns with blind-based counts when blind-based counts are more accurate or complete. In addition to counts of gulls present on the managed islands, we will use the waterbird survey PDA application to record the numbers of Canada geese, herons, and egrets that are observed during waterbird surveys and during hazing activities. For each species, we will record data on the number of individuals, nesting status (if known), and number of eggs for any active goose nests located (clutch size for heron and egret nests will not be determined because they generally nest only in trees or tall shrubs). As for gulls and Caspian terns, we will include counts/estimates of individuals, nesting status, and any observed pre-laying behaviors in the weekly report to the Corps and Reclamation.

Once large numbers of gulls have initiated pre-laying behaviors on the managed islands, island walk-throughs will be increased in frequency in an effort to increase the deterrence for gulls and Caspian terns to lay eggs on the islands. At least two morning walk-throughs starting in the hour before dawn and conducted over the subsequent 3-hour period, and two afternoon walk-throughs conducted over a 3-hour period and ending after dark will be conducted; during each walk-through all gulls and/or Caspian terns will be flushed, with the exception of those gulls known or suspected to be attending eggs. During the period leading up to egg-laying by gulls, colony monitors will stay over-night on the island (with landowner authorization and weather-permitting) so that all gulls can be cleared off the island over-night by hazing after dark, and so that hazing can be initiated as soon as gulls attempt to return to the island in the pre-dawn hours.

If gulls are suspected of having laid eggs in a nest, either outside or inside the passive dissuasion area, the attending adult gull will be approached slowly and cautiously in order to induce the gull to stand-up, but not flush from its nest. This may require carefully approaching the gull nest to within a few meters. Once the gull has stood up and if the observer determines that eggs are present, the observer will gradually back away from the nest in order to avoid flushing the adult gull and exposing the egg(s) to potential predation by other gulls. The number of gull nests with eggs and the number of eggs per nest will be recorded. Each gull egg detected on a managed island will be reported to Pete Loschl and/or Dan Roby as soon as practical (during the same day, at the latest) so that they can forward the information to the Corps and Reclamation. If loss of a gull egg due to gull depredation is observed, this will also be reported the same day to Pete Loschl or Dan Roby. Potential new gull nests will be checked for eggs only if the nest is more than 15 m from the nearest gull nest already confirmed to contain eggs.

If a Caspian tern nest with eggs is suspected anywhere on a managed island, the verification procedure will depend on the context of the suspected Caspian tern nest. If no active gull nests are verified or suspected within 15 m of the suspected Caspian tern nest, then the tern nest will be approached close enough to cause the tern to flush from the nest scrape. If there are known or suspected gull nests within 15 m of the suspected tern nest, then the approach of the suspected tern nest will be slow and cautious so as to preclude gulls from flushing from their nests and exposing their eggs to gull predation. If the Caspian tern on the suspected nest is flushed and reveals one or more tern eggs, those eggs will be collected (under permit) and transported whole in egg containers back to the field house. Collected Caspian tern eggs can be stored temporarily in a refrigerator, for eventual transport to Oregon State University for further analyses.

If a suspected Caspian tern nest is located within 15 m of a known or suspected gull nest containing eggs, the tern nest will not be approached to verify the presence of tern eggs UNLESS previous experience with the nesting gulls in question indicates that they are unlikely to flush from their nests as a result of an observer approaching the suspected tern nest. If a recently laid Caspian tern egg can be collected without causing nesting gulls to flush and expose their own eggs to gull predation, then it will be collected; if the Caspian tern egg cannot be collected without flushing gulls from nearby nests with eggs, than the tern egg will not be collected. Any Caspian tern eggs that are laid on either of the managed islands, whether or not they are collected, will be reported to Pete Loschl and/or Dan Roby as soon as practical so that they can forward the information to the Corps and Reclamation, and for subsequent reporting to the USFWS. Reporting to the Corps and Reclamation will occur during the same day that any Caspian tern eggs are detected or collected for reporting to the USFWS Migratory Bird office in Portland.

If a Canada goose nest with eggs is suspected anywhere on a managed island, the verification procedure will depend on the context of the suspected goose nest, as for suspected Caspian tern nests. If no active gull nests are verified or suspected within 15 m of the suspected goose nest, then the goose nest should be inspected to confirm the nest contents. If eggs are confirmed, they should be counted quickly and the goose down lining the nest should be pulled over the eggs to shield them from the view of predators. This should occur very quickly and researchers should then move away from the nest.

If a heron or egret nest is being built on either of the managed islands in an area that is suitable for gull or Caspian tern nesting (i.e., sparsely vegetated or unvegetated ground), then these pre-laying herons and egrets will be hazed in the process of hazing pre-laying gulls and terns. If a heron or egret nest is suspected of containing one or more eggs (based on the behavior of parent birds at the nest, the verification procedure will again depend on the context of the suspected nest, as for suspected Caspian tern nests. Field technicians will use professional judgment to decide whether a heron or egret nest suspected of containing eggs is in potential gull or Caspian tern nesting habitat. If the suspected heron or egret nest is in densely-vegetated habitat completely unsuitable for gull or tern nesting habitat, it will be avoided. Because field technicians will likely be unable to see into heron and egret nests in trees or tall shrubs, field personnel should observe suspected heron and egret nests in potential tern or gull nesting habitat from a vantage that does not cause the heron or egret to leave the nest. Herons or egrets that hold tight to well-built stick nests when an observer moves slowly to within 15 m will be considered to contain eggs. Heron and egret nests will be recorded as "active" for nests deemed likely to contain eggs or "inactive" for herons/egrets that appear to be pre-breeding or nest building. Researchers will promptly move away from heron and egret nests that likely contain eggs.

Continued gull or Caspian tern nest dissuasion in any area around a known or suspected active goose, heron, or egret nest (i.e., containing eggs) will be carried out using techniques to minimize the possibility of egg loss by these non-target species. These include (1) a slow, indirect approach to the area where a nest is known to be present, (2) averting eyes to avoid direct eye contact with the attending bird, (3) when possible, traveling along the island perimeter to avoid pressuring the attending bird into a preferred escape route in the direction of water, (4) moving relatively quickly away from the area where a nest with eggs is located (the general 30-m vicinity), and, when the possibility of gull nest initiation (egg-laying) appears low, (5) the frequency of gull dissuasion will be temporarily reduced in areas with newly discovered goose nests with eggs and/or goose nests with recently-laid eggs (as suggested by small, likely incomplete clutches [e.g., < 4 eggs]). If feasible, gull dissuasion near incipient goose nest will be reduced for 4-7 days until the nesting geese further invest in their nesting effort and there is less risk of nest abandonment. Gull dissuasion will be reduced locally in a similar manner around newly discovered heron and egret nests that likely contain eggs to reduce the likelihood of nest abandonment during the early incubation phase. If there is a potential risk of egg predation during any short term displacement of a goose from a nest (e.g., by common ravens), (6) the goose down lining the nest will be used to cover the eggs to obscure them from view. Other best management practices to minimize nest abandonment and egg loss by migratory bird species other than Caspian terns will be employed as identified.